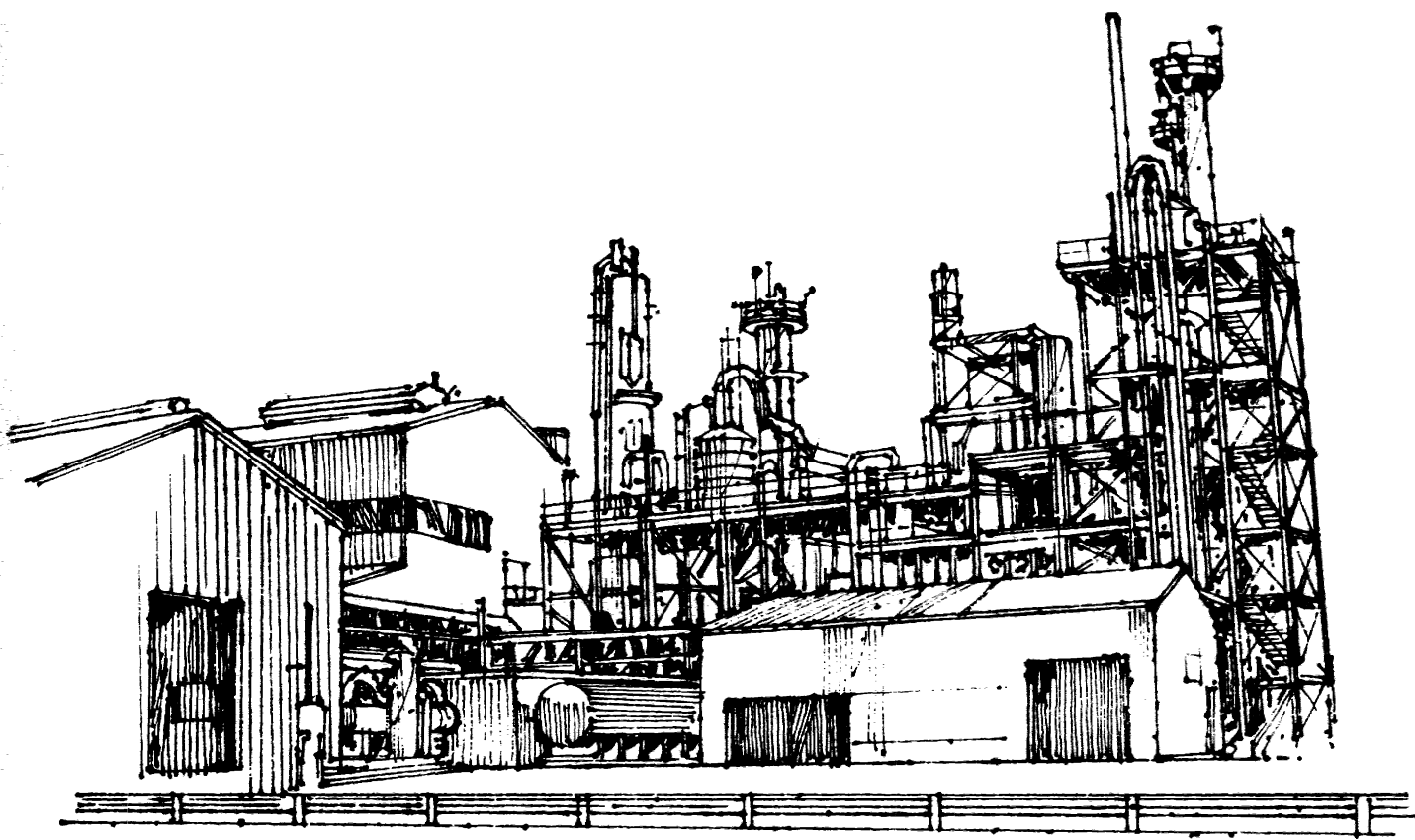


The Changing U.S. Fertilizer Industry

Duane A. Paul, Richard L. Kilmer
Marilyn A. Altobello, and David N. Harrington



United States
Department of
Agriculture

Economic
Research
Service

Agricultural
Economic Report
No. 378

ABSTRACT

Although it is relatively concentrated, the U.S. fertilizer industry appears to respond to demand and supply signals. But the speed of response has slowed because of escalated construction and energy costs and uncertainties regarding the availability of raw materials. Economies of scale have necessitated the construction of larger manufacturing facilities so that firms can be competitive. The effect, rather than the cause, has been an increase in concentration and integration and in barriers to entry.

Manufacturing plant locations have become more oriented to inputs than to markets. Much of the newer nitrogen capacity is in the Gulf Coast States, close to natural gas supplies and to water transportation for both inland and coastal movements. Many new plants are being built as parts of multiproduct complexes, entailing considerable cost savings in coordinating the manufacture of several products at a single location.

The United States is a net importer of potash, but at the minimum it is self-sufficient in nitrogen and phosphate. More than three-fourths of the potash used domestically in fertilizer is of Canadian origin, and nearly all of the North American potash reserves are in Canada.

Key words: Fertilizer industry, Structure, Economies of scale, Nitrogen, Phosphate, Potash, Natural gas, Capital costs, Barriers to entry.

CONTENTS

	<u>Page</u>
SUMMARY	ii
INTRODUCTION	1
AN OVERVIEW OF THE FERTILIZER INDUSTRY	3
Basic Materials Used	3
Trends in Fertilizer Consumption	4
Trends in Fertilizer Production	5
Interrelatedness in the Basic Fertilizer Materials Industries	5
Forms of Business Organization in the Fertilizer Industry	7
NITROGEN FERTILIZER SECTOR	8
Production, Product Flow, and Consumption	8
Imports and Exports	10
Prices	10
Structure, Organization, and Costs	11
Anhydrous Ammonia	11
Urea	22
Nitric Acid	24
Ammonium Nitrate	26
Ammonium Phosphates	27
Ammonium Sulfate	29
Nitrogen Solutions	30
PHOSPHATE FERTILIZER SECTOR	31
Production, Product Flow, and Consumption	31
Prices	33
Structure and Organization	34
Phosphate Rock	34
Phosphoric Acid	36
Concentrated Superphosphate	37
Ammonium Phosphates	37
POTASH FERTILIZER SECTOR	38
Prices	38
Structure and Organization	41
STORAGE AND TRANSPORTATION	44
Types of Storage Facilities	44
Transportation	45
CONCLUSIONS	47
TABLES	48
REFERENCES	79
APPENDIX TABLES	83

SUMMARY

The structure of the fertilizer industry, fertilizer availability, and fertilizer prices have changed in response to demand and supply signals. Following the rapid capacity buildup, the smoothly increasing demand, and declining prices of the sixties, the industry moved through the early seventies with no growth in productive capacity but with record levels of fertilizer use, prices, and profits, particularly in 1973 and 1974. Demand slowed by 1975, as crop prices declined and fertilizer inventories increased. Many fertilizer prices fell almost one-fourth in the year ending in April 1976.

Although all fertilizer use has increased markedly, nitrogen has shown the greatest gain. Between 1949/50 and 1975/76, nitrogen consumption jumped from 1.0 million to 10.3 million tons. Phosphate consumption more than doubled, and potash consumption quadrupled, each reaching a level of 5.2 million tons of nutrient. Overall, the average primary nutrient content per ton of fertilizer material increased from 22 to 43 percent, as farmers' preferences turned toward high-analysis and multinutrient products.

At the beginning of 1976, 57 firms in the United States were producing anhydrous ammonia in 93 plants with a total annual capacity of 17.8 million tons of material. In addition, 21 firms operated 28 phosphate mines, and 11 firms operated 11 potash mines, with annual capacities of 61 and 3 million tons of phosphate rock and potash, respectively. There are extensive linkages within and among the fertilizer industry sectors, especially in the nitrogen and phosphate sectors.

Cooperatives have become an increasingly important part of the fertilizer industry. Presently, their capacities account for 20 percent of anhydrous ammonia, 25 percent of phosphoric acid, and 3 percent of potash in the United States. These organizations have marketed growing amounts of fertilizer materials through an extensive and well-established distribution system.

More than half of the U.S. ammonia production capacity is located in the Delta and Southern Plains States. These areas offer natural gas availability as well as ready access to water, rail, and pipeline transportation. Much of the increased derivative capacity is also located in the Gulf Coast area adjacent to ammonia sites, since there are pronounced economies from onsite use of the basic material for manufacturing derivative products.

Economies of scale are significant in the production of most nitrogenous products, but they are most pronounced for anhydrous ammonia. The average cost of ammonia production declines from \$55 per ton in a 400-ton-per-day plant to \$41 in a 1,000-ton-per-day operation, especially because of differences in the technological designs of the operations. Capital costs comprise nearly half of the average costs in all sizes of operation, emphasizing the large investments in these facilities. Variable costs are also significant, however, as a doubling of the price of natural gas from \$.50 to \$1.00 per thousand cubic feet increases production costs by 47 percent. And a tripling to \$1.50 boosts production costs by 95 percent.

The United States accounts for only 8 percent of world phosphate rock resources but 38 percent of production. Even so, changes in the prices and organizational structure of the phosphate sector have been similar to those for the nitrogen sector. Prices of most phosphatic materials were relatively stable from 1966 to 1972. Then, in some cases, prices more than doubled between 1973 and 1975. Concentration has declined, but vertical integration has increased, as many phosphate rock firms also produce phosphoric acid and other derivatives. Among the derivatives, phosphoric acid capacity has shown the most growth, a trend that is likely to continue.

More than 90 percent of the potash used in the United States is for fertilizer. U.S. production of potash peaked in 1966 and has declined since then. Concurrently, increased amounts of potassic materials have been imported, especially from Canada. Canadian ores are of higher analysis than domestic minerals, and Canadian mines offer lower transportation costs to the major Midwest market.

The structure of the domestic potash industry has ranged from atomistic in the early part of this century to relatively concentrated since late in the fifties. U.S. reserves are only 2 percent of the world's total reserves and are located in California, Utah, and New Mexico. Nearly all of the North American reserves are in Canada, and the United States is likely to continue to fill most of its potash needs from Canadian sources.

Although a reasonable degree of price flexibility indicates that the industry is responsive to supply and demand conditions, uncertainties in several areas have slowed the rate of adjustment to different market signals. Sharply escalating construction and energy costs, uncertain availability and prices of natural gas, and sharply peaked seasonal demand indicate that future additions to industry capacity will continue to be made by large, diversified businesses operating in other markets in addition to those for fertilizer.

THE CHANGING U.S. FERTILIZER INDUSTRY

By Duane A. Paul, Richard L. Kilmer, Marilyn Altobello,

and David N. Harrington^{1/}

INTRODUCTION

A continuous supply of chemical fertilizers is vital to U.S. farmers and consumers, because crop output and food availability depend directly on fertilizer use. In 1975, farmers spent \$6.6 billion for fertilizers, which flowed through a complex of manufacturers, formulators, blenders, and dealers. The industry which supplies those products is a highly capital-intensive, multibillion-dollar segment of our economy that is expected not only to provide products which are vital to our agricultural productivity, but also to generate adequate returns for investors and owners in the industry. However, the industry appears to be subject to major fluctuations which directly affect fertilizer prices, supplies, and industry profits.

The importance of fertilizers in maximum agricultural production is well established. Certainly, to a point, crop yields are enhanced by adding certain chemicals to the soil. It is often assumed that fertilizer supplies are inexhaustibly available and that attaining large yields is merely a matter of applying correct amounts of the materials. However, the availability of fertilizers to the agricultural sector depends on several forces not felt directly by farmers, but these forces do affect the structure of the industry--the sizes and number of firms and plants, concentration of buyers and sellers, and conditions of entry. These elements bear directly on both the present and future supplies of materials and, consequently, on the prices of fertilizer materials.

Fertilizer prices, however, are the product of demand factors as well. In the sixties and through 1970, demand grew at relatively uniform rates, but growth in demand was outweighed by large increases in productive capacity. Fertilizer prices fell. By mid-1971, the growth of productive capacity almost stopped because of unprofitability. Several firms left the industry. Through a combination of circumstances influencing both supply and demand, fertilizer prices soared nearly 150 percent between April 1971 and April 1975. The price of anhydrous ammonia rose to \$265 per ton, concentrated superphosphate to \$214 per ton, and muriate of potash to \$102 per ton (61).^{2/} At the same time, however, production costs skyrocketed because of greater capital and energy costs.

^{1/} Paul and Harrington are Agricultural Economists, Natural Resource Economics Division and National Economic Analysis Division, respectively, Economic Research Service; Kilmer and Altobello were formerly Agricultural Economists for ERS and are now Assistant Professors at the Department of Food and Resource Economics, University of Florida at Gainesville, and at the Department of Agricultural Economics, University of Arizona at Tucson, respectively.

^{2/} Underscored numbers in parentheses refer to references listed at the end of the report.

Since early in 1975, the fertilizer market has shifted significantly from the tight demand-supply situation of the past 4 years. Higher fertilizer prices and lower than expected 1975 crop prices reduced fertilizer demand by 9 percent between the 1973/74 and 1974/75 fertilizer years. Lower demand caused an inventory buildup and a noticeable weakening of prices. Anhydrous ammonia, urea, and ammonium nitrate prices paid by farmers decreased more than 27 percent between April 1975 and April 1976. For the same period, phosphate rock prices declined 26 percent, and potash prices decreased 6 percent. Total 1975/76 consumption increased 15 percent over 1974/75, but October 1976 prices were about 12 percent lower than in October 1975.

The rapid increase followed by the sharp fall in prices has caused concern among members of the fertilizer industry, farmers, and policymakers. On the one hand, some members of the industry see the past 4 years as similar to the initial phase of other periods, such as 1964-69 for anhydrous ammonia and 1963-68 for phosphate rock, in which there were declines in product prices, an accelerated buildup of productive capacity, and extremely low profit levels. Farmers, on the other hand, have seen their fertilizer prices more than double since 1971. Policymakers are concerned about the effects of price and production gyrations on producers, farmers, and consumers.

This report attempts to place these issues in perspective by discussing the structural organization and operation of the industry. The objectives are to discuss: (1) the trends in production and consumption of fertilizer materials; (2) the current structure of the fertilizer industry in terms of the size, number, and locations of firms and plants, and the nature of integration, conglomeration, and product flow throughout the industry; (3) the costs of manufacturing nitrogen fertilizer products; and (4) some of the problems the industry faces, such as environmental regulations and future availability and cost of natural gas.

The focus of this study is on the manufacturing level of the three primary fertilizer nutrients--nitrogen, phosphate, and potash. Structure, product flow, and cost information is presented for nitrogen, but the information on phosphate and potash excludes cost and other technical data. The structural dimensions considered include: (1) concentration, (2) factors influencing firm entry into and exit from the industry, (3) vertical integration, (4) conglomerate characteristics, (5) growth of market demand, (6) the ratio of fixed cost to total cost, and (7) diversification.

The cost figures presented are derived from published budgets and from unpublished materials provided by firms which offer engineering and consulting services to the fertilizer industry. Actual costs per ton could not be obtained from the industry, as this information is considered confidential for competitive and antitrust reasons.

AN OVERVIEW OF THE FERTILIZER INDUSTRY

The production and consumption of fertilizer products involve the extraction of natural resources, combination of these products with other inputs in highly complex manufacturing plants, incorporation of the nutrient-carrying products into fertilizers of the strengths and forms desired by farmers, movement of fertilizers to the locations where they are needed, and, ultimately, application to soil or plants. Accordingly, the "fertilizer industry" incorporates elements of not only the manufacturing sector but also of the natural resources and marketing segments of our economy.

Basic Materials Used

The origins for nitrogen (N), phosphate (P2O5), and potash (K2O) values in fertilizer products are found in different natural resources. (Note that numerical elements of chemical compounds are not subscripted in this report). The least expensive and most readily available nitrogen source is air, but most plants cannot assimilate nitrogen directly from the atmosphere. Consequently, to serve as a source of nitrogen for such plants, atmospheric nitrogen must be altered or combined with other elements. Anhydrous ammonia, which results from combining atmospheric nitrogen with hydrogen, is the nitrogenous material most commonly produced for use as fertilizer. Phosphate, however, is provided by phosphate rock, which is mined and processed into several phosphate-carrying intermediates. Potash is derived from potassic ores, which are mined, processed, and applied either singly or with other products as multinutrient fertilizers.

Nearly 95 percent of the anhydrous ammonia produced domestically uses natural gas as the hydrogen source for combination with atmospheric nitrogen; the hydrogen sources for the remaining 5 percent are coke oven and refinery gases and chlorine cells. Prior to World War II, however, nearly all ammonia plants used coke-oven gas as the source of hydrogen. There were many reasons for this switch, but those most responsible were the development of efficient processes using petroleum and the lower investment costs and favorable price structures for natural gas and liquid hydrocarbons. The processes involved in coal gasification are elaborate. Investment, operating, and maintenance costs are all substantially larger than those of comparably sized petroleum-based plants.

Phosphate rock is the basic source for all phosphate products, but it is concentrated sufficiently in only a few regions to justify its removal from surface soils.^{3/} After the rock has been mined, it is washed, dried, and ground. The ground material is then mixed with sulfuric acid or phosphoric acid to produce several different products.

Potassium chloride is the most important mineral supplier of potash, with 95 percent used for fertilizer (57). Potash sources include both salt deposits and brines, with salt deposits being the more important. Before the potash leaves the mine, the salts and brines are processed to obtain the K2O in a more concentrated

^{3/} Phosphate rock material mined in the United States in 1975 averaged 12.9 percent P2O5. After beneficiation, the marketable rock product averaged 32.5 percent P2O5.

form. Potassium oxide (K₂O) concentration ranges from only a trace to 35 percent or more. After processing, pure muriate of potash (potassium chloride) would contain 63.18 percent K₂O; most commercial muriate of potash is less than pure but still more than 60 percent.

Trends in Fertilizer Consumption

The quantity and the quality of fertilizer consumed in the United States have increased steadily since 1950 (table 1).^{4/} By 1976, total materials consumed had increased 2.7 times, and primary nutrient consumption had increased more than fourfold. Hence, average primary nutrient content per ton of material increased from 22 to 43 percent.

Consumption of nitrogen increased most significantly. Of total primary nutrients consumed in 1950, approximately 25 percent were nitrogen; 48 percent, phosphates; and 27 percent, potash. By 1960, nitrogen consumption slightly exceeded phosphates and represented 37 percent of total primary nutrients consumed. In 1976, 50 percent of the primary nutrients consumed was nitrogen; 25 percent, phosphate; and 25 percent, potash.

There have been significant shifts in regional consumption patterns since 1950. At that time, the Appalachian and Southeast crop production regions accounted for about 38 percent of total primary nutrients consumed in mixtures and direct application materials in the United States. By 1975, with a decline in agricultural activity in those regions relative to other areas, their share had fallen to 17 percent. Conversely, the share of the Corn Belt grew from 18 percent in 1950 to 32 percent in 1975 (table 2). Further, the Corn Belt accounted for 29, 33, and 40 percent of the 1975 U.S. consumption of nitrogen, phosphate, and potash, respectively (61).

Farmers have also varied the forms of products they purchase. In the forties and fifties, about 45 percent of the nitrogen, 76 percent of the phosphorus, and 90 percent of the potash used as fertilizer were sold to farmers as bagged, mixed fertilizers. Mixed fertilizers remain the dominant form for farm use of phosphate and potash, and ammonia and ammonia-based products have become the primary nitrogen-carrying materials. In 1974/75, 82 percent of the phosphorous, 67 percent of the potash, but only 24 percent of the nitrogen used as fertilizer in the United States were sold to farmers as mixed fertilizers (62). Conversely, direct application of anhydrous ammonia, ammonium nitrate, nitrogen solutions, and urea accounted for 69 percent of total nitrogen fertilizer consumption.

Since late in the fifties, bulk blending facilities have become increasingly popular. These plants serve essentially local markets, and their number has increased from 201 in 1959 to over 5,000 at present. They provide bulk delivery of fertilizer materials to farms and in 1974 handled 49 percent of the fertilizers sold to farmers. An advantage that bulk blenders enjoy, relative to producers of bagged materials, is the ability to formulate or customblend many different grades of fertilizer by using such primary materials as ammonium phosphates, urea, ammonium nitrate, and potash.

^{4/} All tables are grouped at the end of this report.

Trends in Fertilizer Production

Since 1950, there have been large increases in the capacity to produce nitrogen and phosphate fertilizers and their basic materials, anhydrous ammonia and phosphate rock. The largest increases in ammonia production occurred between 1964 and 1967 (fig. 1), after the introduction of a technologically advanced plant design early in the sixties. During those 4 years, ammonia production increased 61 percent from 7.6 to 12.2 million tons. Output declined slightly in 1968 to 12.1 million tons, but since then it increased to 16.4 million tons in 1975 (56).

Phosphate rock output has grown sharply since late in the fifties. From an annual average of 13.5 million tons during 1950-55, marketable rock production expanded to 19.6 million tons in 1960, 39 million tons in 1966, and 48.8 million tons in 1975. Much of the rock has been utilized to produce phosphoric acid, an important chemical for not only phosphatic fertilizers but also many industrial compounds.

Domestic production of potash rose from 1.3 million tons of K₂O in 1950 to over 3.3 million tons in 1966. Since that time, U.S. production has fallen considerably, and much of the potash used is imported, principally from Canada. At present, Canada supplies approximately 75 percent of the potash consumed in the United States. In 1975, U.S. and Canadian production of potash were 2.5 and 6.0 million tons of K₂O, respectively.

Table 3 presents data which describe in general terms the basic structure of each material industry at the beginning of 1976. On the average, each firm in the ammonia sector had two plants, and each phosphate and potash firm operated a single mine.

Interrelatedness in the Basic Fertilizer Materials Industries

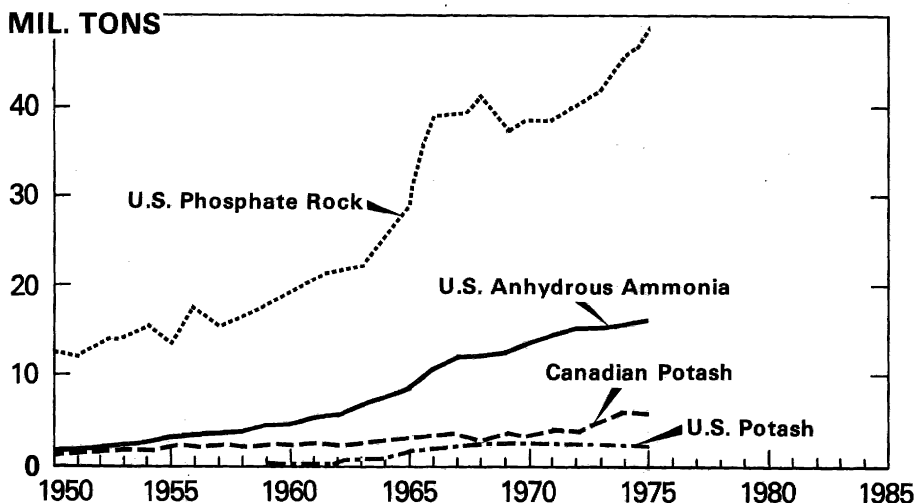
Anhydrous ammonia and phosphate rock, both separately and jointly, are basic materials for derivative products. But not all of these products are used as fertilizer ingredients.

Anhydrous ammonia is used directly in the production of nitric acid, ammonium nitrate, urea, nitrogen solutions, synthetic ammonium sulfate, and ammonium phosphates (fig. 2). Nitric acid is combined with ammonia to produce ammonium nitrate, and ammonium nitrate, urea, and anhydrous ammonia are used in various proportions to produce nitrogen solutions. Phosphate rock derivatives include phosphoric acid and the superphosphates. Phosphoric acid is combined with anhydrous ammonia to produce ammonium phosphates and with phosphate rock for concentrated superphosphate.

There are also significant linkages among the basic materials industries. Thirteen ammonia producers, controlling 26 percent of total U.S. ammonia capacity, also control 59 percent or 33.5 million tons of domestic phosphate rock capacity (table 4). Conversely, only two ammonia producers produce potash, with an aggregate capacity of 530,000 tons or 16 percent of U.S. K₂O capacity.

Phosphate rock producers are also integrated into the sectors producing nitrogen and potash. Besides anhydrous ammonia, rock producers manufacture several ammonia derivatives. Eight rock producers manufacture urea and control 23 percent of aggregate capacity (table 5). Three rock producers hold 26 percent of the total U.S. ammonium sulfate (prime) capacity. Two rock producers possess 560,000 tons or 17 percent of domestic potash capacity.

PRODUCTION OF SELECTED FERTILIZER MATERIALS, UNITED STATES AND CANADA

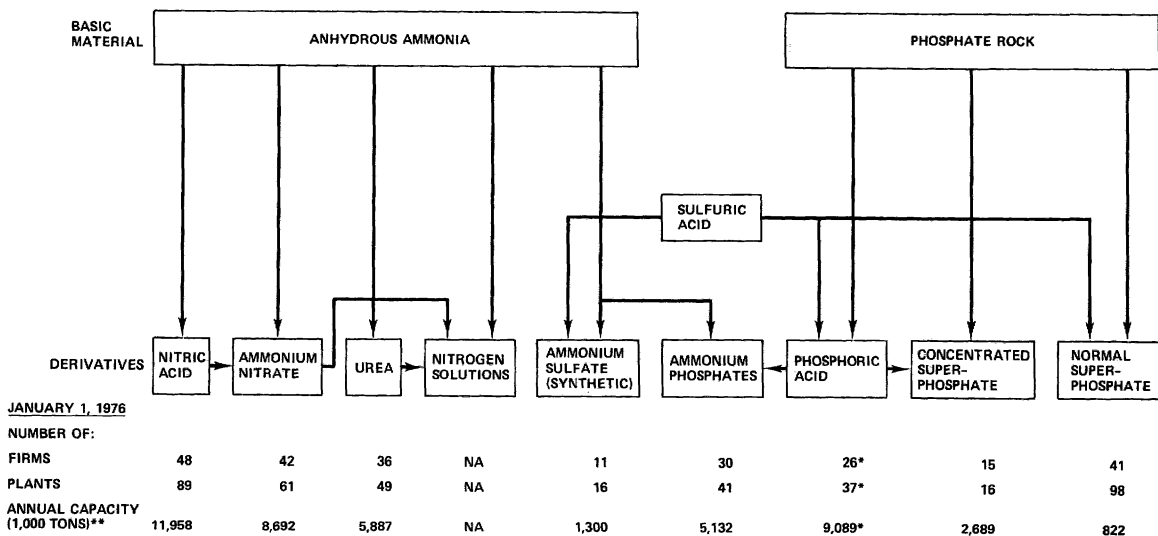


USDA

NEG. ERS 2677-77 (1)

Figure 1

LINKAGES BETWEEN BASIC NITROGEN AND PHOSPHOROUS MATERIALS AND THEIR DERIVATIVES, JAN. 1, 1976



NA = NOT AVAILABLE.

*WET-PROCESS ACID.

**NITROGEN PRODUCTS, EXCEPT AMMONIUM PHOSPHATES, ON MATERIAL WEIGHT BASIS; OTHERS ON P_2O_5 BASIS.

Figure 2

Potash producers are integrated into the production of the other two nutrients, but not as extensively as the integration of nitrogen and phosphorous manufacturers into different nutrient lines. Two potash producers are engaged in phosphate rock production and control 27 percent of total U.S. rock capacity (table 6). Ownership is much less significant in the anhydrous ammonia sector, since 2 potash producers control less than 5 percent of domestic ammonia capacity.

Forms of Business Organization in the Fertilizer Industry

Privately owned corporations own much of the domestic fertilizer productive capacity. Many of these firms have been associated with the industry for several decades, and others are relatively new entrants. Among the largest corporations, sales of fertilizer products usually represent a relatively small percentage of total firm sales. Nonetheless, fertilizers are an important part of total company activities, and several firms have recently added production capacity.

Cooperatives have also played an important role in the growth of the U.S. fertilizer industry. Farmers' purchases of fertilizers through these organizations more than quadrupled between 1950 and 1970, and the cooperatives' aggregate market share grew from 15 to 32 percent (37). The cooperatives are involved in both manufacturing and marketing activities, producing substantial amounts of basic materials and their derivatives and distributing them through an extensive system of local facilities.

On January 1, 1976, cooperatives were operating 18 anhydrous ammonia plants, representing about 20 percent of U.S. capacity (51). In the phosphate sector, cooperatives operated 8 wet-process phosphoric acid plants with nearly 25 percent of U.S. capacity; and in potash, one mine with about 3 percent of U.S. capacity. Cooperatives also were operating substantial amounts of derivative capacity: Urea, 11 plants and 28 percent of U.S. capacity; ammonium nitrate, 8 plants and 17 percent; ammonium phosphates, 11 plants and 28 percent; and concentrated superphosphate, 3 plants and 30 percent.

NITROGEN FERTILIZER SECTOR

The nitrogen manufacturing sector is among the most complex segments of the fertilizer industry. The complexity of the sector arises not only from its size and the mass of resources it embodies, but also from its structural organization. Efficient production of nitrogen products requires the use of large-scale plants for which capital costs are very large. Further, the energy required to produce many of the products is considerable. These conditions have an important bearing on costs of production and the responsiveness of nitrogen supplies to the needs of agriculture.

Production, Product Flow, and Consumption

Most of the anhydrous ammonia produced in the United States is applied directly to the soil or is transformed into ammonia derivatives, such as ammonium nitrate, urea, nitrogen solutions, synthetic ammonium sulfate, and ammonium phosphates. The transformation results in liquid or solid products that are easier to store, transport, or mix with other fertilizer nutrients. On the one hand, anhydrous ammonia is more difficult to store and handle because of its gaseous nature above 33 degrees below zero C. On the other hand, anhydrous ammonia is more concentrated than ammonia derivatives (app. table 1). For example, 1.78 tons of urea are required to deliver the same nitrogen as 1 ton of anhydrous ammonia. About 7.5 tons of mono-ammonium phosphate (11-48-0) are necessary to provide the equivalent amount.

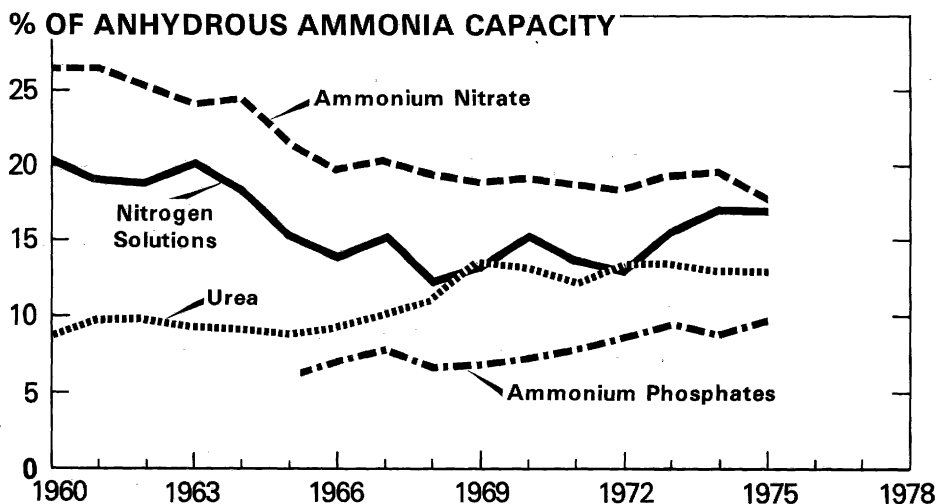
Anhydrous ammonia production increased 228 percent between 1960 and 1975, and 76 percent of the increase occurred between 1960 and 1967. But total nitrogen fertilizer consumption increased more slowly. Between 1960 and 1975, consumption rose 214 percent, and 56 percent of the increase occurred by 1967 (61). This indicates that an increasing amount of anhydrous ammonia production has been diverted to nonfertilizer use. Over time, the percent of anhydrous ammonia consumed in nonfertilizer uses has increased to a high of 27.6 percent in the 1974/75 fertilizer year.

The percentage of total domestic anhydrous ammonia production that is consumed in urea and ammonium phosphates has generally increased over time. But the percentage incorporated into nitrogen solutions has increased since only 1968 (fig. 3). The proportion used to produce ammonium nitrate is the largest among the derivatives, but it has declined because ammonium nitrate production capacity has not grown so much as higher analysis products, such as urea and nitrogen solutions.

Since early in the sixties, increasing amounts of total fertilizer nitrogen consumed have been as ammonia and urea. An important reason for this trend is the greater significance of transportation costs in the prices that farmers pay for fertilizers, as producing plants have become more input- than market-oriented. Consequently, it is less expensive per unit of nutrient to purchase higher analysis materials, and farmers have shifted their preferences from the lower analysis products, such as ammonium sulfate and ammonium nitrate, to nitrogen solutions, urea, and ammonium phosphates (fig. 4).

It is likely that farmers will continue to demand high-analysis, low-cost-per-unit nutrient products, such as anhydrous ammonia, despite ammonia's special handling and storage requirements. Further, the amounts of ammonia and ammonia derivatives that are applied directly, rather than mixed and diluted, are likely to continue to

U.S. ANHYDROUS AMMONIA CAPACITY USED TO PRODUCE SELECTED DERIVATIVES

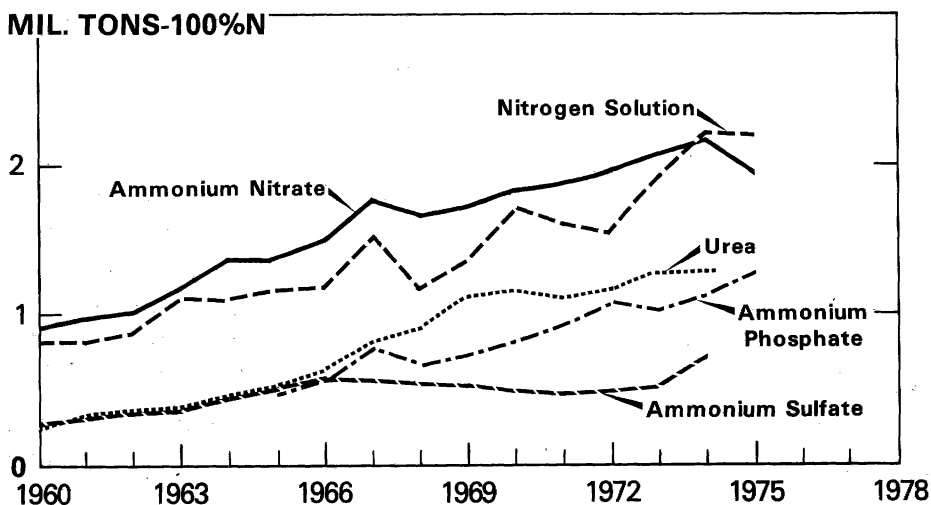


USDA

NEG. ERS 2670-77 (1)

Figure 3

QUANTITY OF DOMESTIC AMMONIA DERIVATIVES CONSUMED FOR FERTILIZER



USDA

NEG. ERS 2668-77 (1)

Figure 4

grow. Direct application of anhydrous ammonia offers the highest concentration of nitrogen among all nitrogenous products, and it is especially popular in the Corn Belt and the Northern and Southern Plains (61). However, large amounts of ammonium nitrate, urea, and nitrogen solutions are also applied directly.

Imports and Exports

From 1961 through 1964, the United States was a net importer of nitrogen (fig. 5). Rapid growth of domestic nitrogen production capacity and the Freedom From Hunger programs reversed the trend, and the United States became a heavy exporter until 1969. At that time, the buildup in capacity virtually ceased, and the net U.S. export balance declined from 900,000 tons of nitrogen to less than 200,000 tons in 1971. Exports were again heavy in 1973. However, with strong domestic demands in 1974 and 1975, the trade balance was trimmed to net exports of 201,000 tons in 1974 and net imports of 80,000 tons in 1975. In the year ending June 30, 1976, exports exceeded imports by 113,000 tons (35).

At present, U.S. imports and exports of nitrogen are almost equal. The greatest amounts of imported nitrogen are provided by anhydrous ammonia and urea, accounting for over 70 percent of nitrogen imports in the year ending June 30, 1976 (35). Exports of anhydrous ammonia have declined considerably since the year ending June 30, 1974, as the domestic price and demand situation has been more favorable than foreign markets to U.S. producers, especially after the relaxation of price controls. However, urea exports have increased over 100 percent since June 30, 1974, because world demand for urea has been increasing, domestic demand has dropped, and new factory facilities have begun to produce.

Prices

Nitrogen prices paid by farmers began to decrease in 1964 as the overcapacity of some factories started to show an effect (table 7). By 1969 and 1970, supply was more in balance with demand, and prices stabilized. By that time, however, additions to productive capacity had nearly stopped. The mounting global concern about adequate food supplies fueled stronger fertilizer demands worldwide, and international prices began to rise in 1971. Late in 1971, price controls on fertilizers caused a rapid growth in nitrogen fertilizer exports from the United States, as export prices were exempt from controls and were much higher than domestic regulated prices. As millions of acres previously in set-aside programs were released for production, minor to acute shortages of many fertilizer products developed in the United States. But the situation eased after price controls were lifted in late 1973. By this time, however, world market prices had increased even more sharply, and domestic prices spurted up as well. Nonetheless, U.S. farmers consumed a record (at that time) 9.2 million tons of nitrogen in the year ending June 30, 1974.

Prices for most nitrogen fertilizers peaked early in 1975, as crop prices had begun to fall markedly in the last quarter of 1974. As a consequence, nitrogen consumption during 1974/75 decreased 6 percent from a year earlier. Increased inventories, a net import situation, and increased production capacity caused an increase in available fertilizer supply during 1975/76 that was accompanied by a decline in fertilizer prices to levels 25 percent below those of a year earlier.

The costs of producing nitrogen fertilizers have also changed markedly since early in the sixties. Manufacturing costs dropped with the adoption of centrifugal

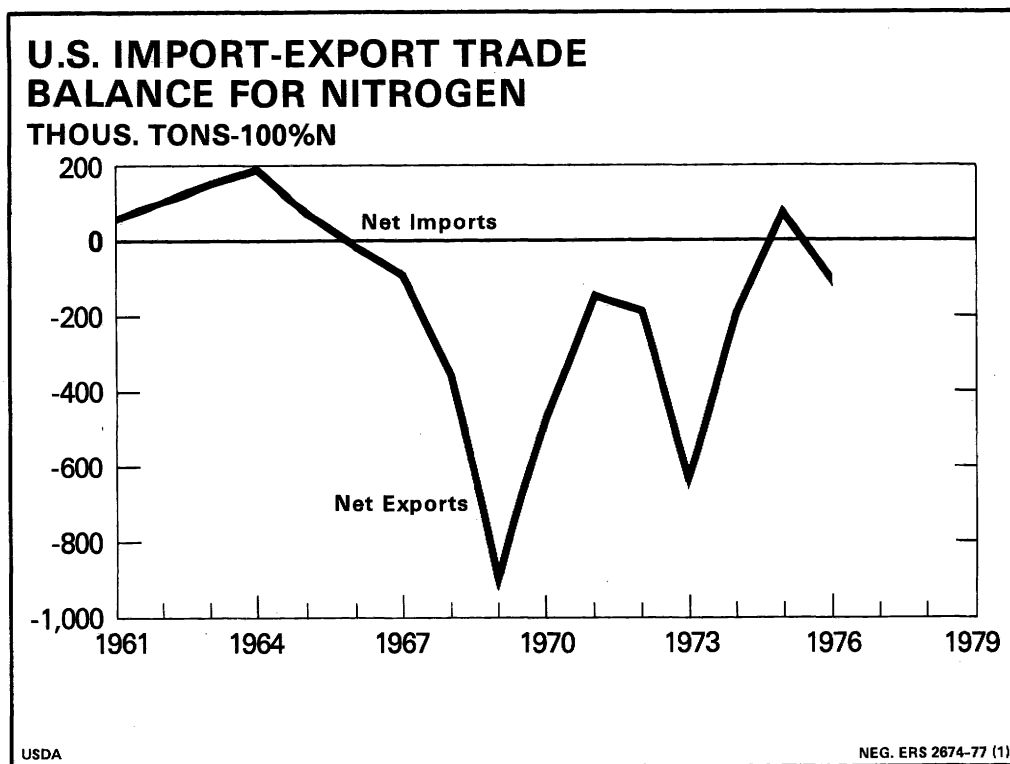


Figure 5

compressors in larger plants and improvements in plant energy requirements. Since that time, dramatic increases in construction costs and natural gas prices have caused a significant upturn in ammonia production costs. As plant construction costs have skyrocketed, so also have the capital costs per ton of product. Natural gas costs have jumped and will likely continue to increase with higher prices for both interstate and intrastate gas. These increases have been reflected directly in the costs of producing ammonia and, consequently, ammonia derivatives.

Structure, Organization, and Costs

No single measure adequately describes the structure of the entire nitrogen industry, because the industry produces many products and has important linkages within itself and with other industries. The structure and operation of the anhydrous ammonia sector, however, have important effects on the rest of the nitrogen industry.

Anhydrous Ammonia

The process for synthesizing anhydrous ammonia was developed in Germany and was one of the major technological accomplishments of the time. Commercial production began in Germany in 1913 and commenced in the United States with the opening of a plant in Syracuse, New York, in 1921. By 1940, there were seven anhydrous ammonia producers in the United States with a total annual production capacity of 475,000 tons. Industry concentration was very high, as the four largest firms accounted for 96 percent of total capacity in 1940 (23).

From 1951 to 1969, the concentration of the top four and top eight ammonia firms decreased, as both total capacity and the number of firms increased (fig. 6). Between 1960 and 1969, anhydrous ammonia capacity more than tripled, and firm numbers continued to increase. Between 1964 and 1969, anhydrous ammonia production increased 1.7 times, and capacity increased 2.2 times. By 1969, capacity utilization had dropped to 70 percent. The number of firms declined from 71 in 1969 to 59 in 1975, as some firms merged and others left the industry.

During the sixties, there were also important changes in the geographical concentration of ammonia production. The most notable trend was a shift from a scattered, market-oriented pattern of production to one based heavily in the Delta States (Mississippi, Arkansas, and Louisiana) and in the Southern Plains States (Oklahoma and Texas). Between 1960 and 1975, the proportion of total domestic anhydrous ammonia capacity in these States rose from 32 to 52 percent (table 8), but their share of nitrogen consumption dropped from 18 to 14 percent (table 2). In contrast, however, in the Appalachian and Corn Belt regions, the proportion of total domestic anhydrous ammonia capacity decreased from 33 percent to 20 percent, but consumption increased from 27 to 34 percent. Thus, the shift in the geographical concentration of anhydrous ammonia production capacity has generally been away from areas of increased nitrogen consumption.

Several factors have been responsible for this shift. First, decisions on ammonia plant locations are based heavily on the availability and costs of transporting natural gas, the primary raw material in anhydrous ammonia production, versus those for ammonia. Natural gas supplies are relatively greater and the costs of gas and other utilities are lower in the Delta and Southern Plains States than in other parts of the country. In 1975, Texas, Louisiana, and Oklahoma produced 16 trillion cubic feet of natural gas, 81 percent of total U.S. marketed production (63).

A second major reason for the shift to Gulf Coast production sites was changes in storage technology and capacity. Ammonia producers had considered the area as desirable for some time, but they had been hampered from moving to the area by a lack of adequate storage facilities in outlying market areas. Technological advances in storage facilities in the fifties and sixties and the construction of pipelines in the seventies have made it feasible to install large-scale cryogenic vessels in the area of use.

A third major reason for the shift to the Gulf Coast region was the ability to use interior and coastal waterways for barge movements of ammonia. This capability allows greater latitude in servicing domestic markets and furnished easier transportation for exports. Thus, many producers favored the Gulf Coast area not only for its relatively greater supplies of natural gas, but also for the overall flexibility provided in firm planning with respect to domestic and export markets. If U.S. factory capacity is overdeveloped as in 1968-72, Gulf Coast plants will likely have a significant advantage in market alternatives, relative to inland producers.

It should be noted that location decisions are also affected by other factors. Many producers manufacture ammonia for direct application to soil in its gaseous form and for production of derivatives. The costs of transporting the raw materials for these products must also be incorporated into the final decision on ammonia plant location. In the case of ammonium phosphates, producing plants are best located near points of phosphate rock production which have adequate water transportation capability. The Gulf Coast area and Florida meet both of these criteria.

PRODUCTION CAPACITY AND CONCENTRATION RATIOS OF THE ANHYDROUS AMMONIA INDUSTRY

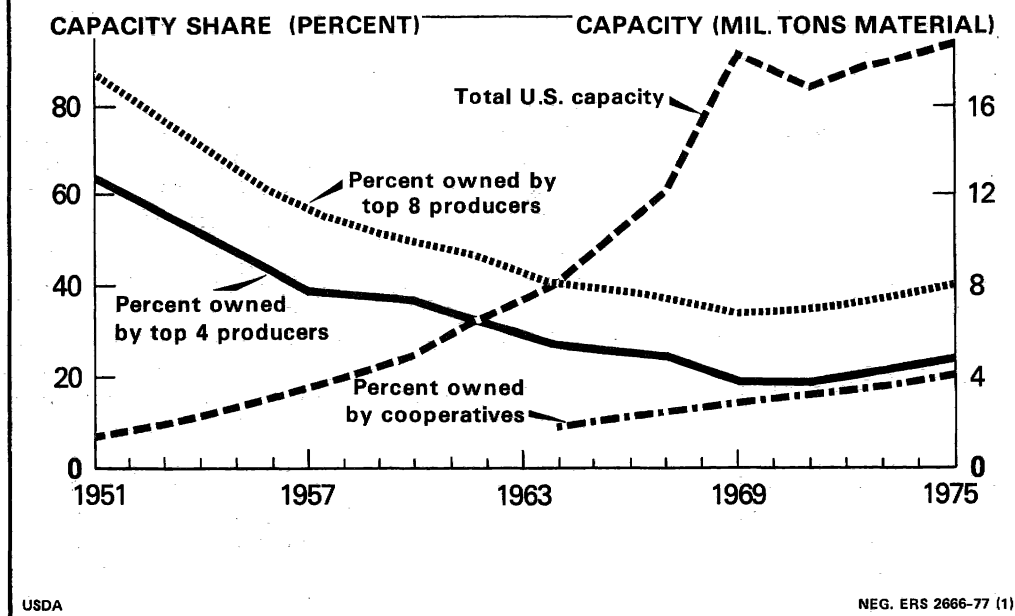


Figure 6

Concentration and diversification.--Anhydrous ammonia producers and their parent firms are involved in the production and distribution of a wide range of goods and services (fig. 7). At least 76 percent of the anhydrous ammonia producers (44 firms) or their parent companies produce chemicals and allied products other than fertilizer materials. At least 35 percent (20 firms) manufacture miscellaneous plastic products. And at least 31 percent (18 firms) are involved in petroleum refining and related industries. As an indication of backward integration into raw materials production, at least 24 percent (14 firms) are involved in crude petroleum and natural gas extraction, with 5 of the 14 firms engaged in natural gas production and distribution.

In 1975, 23 ammonia firms were owned by parent corporations which had primary activities other than fertilizer manufacturing. Their share of capacity has varied over time. Since 1960, the proportion owned by petroleum and chemical firms has intermittently decreased and increased, with a declining phase occurring in 1975 (fig. 8).

Vertical integration has increased in the nitrogen industry (table 9). But the percentage of derivative capacity controlled by the anhydrous ammonia firms increased only 4 percentage points during 1964-75, although the anhydrous ammonia capacity controlled by these vertically integrated firms grew. Much of the gained derivative capacity was for ammonium phosphates (table 10). Ammonia producers have also increased their urea capacity, but they have reduced their ammonium nitrate capacity.

INVOLVEMENT OF ANHYDROUS AMMONIA PRODUCERS AND THEIR PARENT FIRMS IN THE PRODUCTION OR DISTRIBUTION OF OTHER PRODUCTS, 1975

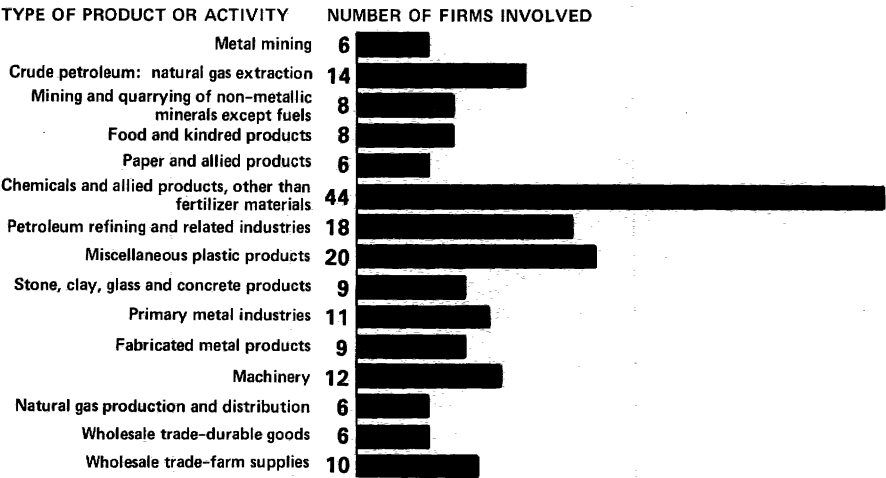


Figure 7

PROPORTION OF ANHYDROUS AMMONIA PRODUCTION CAPACITY

Controlled by the Petroleum Industry, Chemical Industry, and Cooperatives, Selected Data

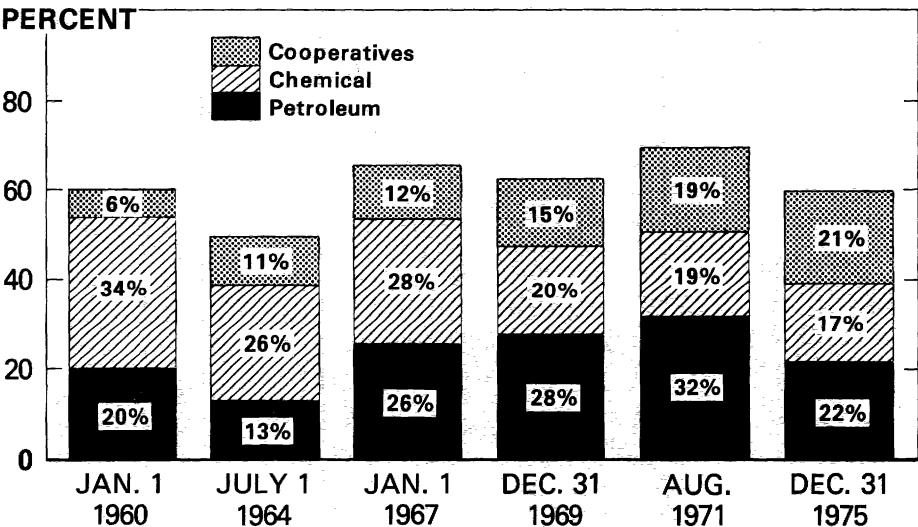


Figure 8

During the anhydrous ammonia capacity buildup from 1964 to 1969, several firms entered the industry without derivative capacity. Even though the number and percentage of integrated anhydrous ammonia firms increased during that period, the anhydrous ammonia capacity owned by integrated firms increased only 2 percent. Between 1969 and 1975, anhydrous ammonia firm numbers decreased, but the proportion of anhydrous ammonia capacity owned by integrated firms increased to 91 percent. Thus, many of the firms which left the anhydrous ammonia industry did not possess derivative capacity.

Much of the increase in vertical integration is closely related to the trend toward agglomeration of production facilities. The advantages of such colocation are many. First, the efficient, competitive production of urea, ammonium nitrate, and other derivative products depends directly on an adequate supply of ammonia, the primary raw material used in these products. Many of the newer process lines for derivatives have been built in conjunction with or as complements to existing ammonia plants. Nearly all of the urea plants operating on January 1, 1976, were located adjacent to ammonia plants. Over two-thirds of the ammonium nitrate plants were located at the same site as an ammonia facility. There were nearly 30 ammonia-ammonium nitrate-urea complexes and approximately 15 ammonia-ammonium phosphate facilities. And, 10 ammonia-phosphoric acid complexes and 30 phosphoric acid-ammonium phosphate complexes were operating. Each nitrogen solutions plant was located adjacent to at least one ammonia, ammonium nitrate, or urea plant. The incentives for captive use of the output of one process line as an input into others are not new to the nitrogen industry, however, as ammonia plants operating as early as the thirties were components of integrated product lines of large companies.

There are other reasons for colocation of production facilities. Onsite use of ammonia in urea, ammonium nitrate, and other products eliminates the necessity of transporting the raw material to other locations for derivative manufacturing. Further, similar labor skills are required to operate all of the plants, and agglomeration of production facilities enables producers to spread the costs of such offsite facilities and services as water-treatment plants, cooling towers, railroad sidings, roads, utilities, storage (in some cases), administrative and maintenance buildings, parking lots, and loading docks. In addition, there can be significant economies in administration and maintenance of the entire complex.

Colocation of production facilities is an important part of the "total-systems" production and marketing approach that producers are using. Such an approach has become essential. Capital and energy costs of production are increasing, and planning efforts are expanding to better meet the seasonal demand for the movement of fertilizer. Besides the economies gained from integrated onsite process lines and sharing of supporting offsite facilities, agglomeration consequently requires the consideration of storage and transportation functions and of the marketing system in total.

Manufacturing processes and technology.--There have been tremendous advances in fertilizer productive technology in the last three or four decades. Through the early part of the seventies, these advances were accompanied by a reduction in the unit cost of producing fertilizer, thereby making these products more economical for users. Along with many of the technological advances, a trend has also developed toward building larger manufacturing plants, as economies of scale are significant for many types of fertilizer plants. This cost behavior has direct implications for longrun planning by the industry and, consequently, for future fertilizer supplies.

Fertilizer production facilities are chemical complexes, parts of which are necessary for the actual production of a product and other parts for providing auxiliary services. The battery limits of a plant include only the equipment and buildings essential to the manufacture of a product or group of products. Offsite

facilities include the land on which the production facility is located and other equipment related to the plant. A grass roots plant encompasses both the battery limits plant and related offsite facilities. Although the actual process lines are basically separate and independent activities, there may be some process integration among plants located at the same site.

The first ammonia plant started operating in Germany in 1913 using the Haber-Bosch process. Although many modifications of that process have been made in the various steps of ammonia preparation, the Haber-Bosch technique represented the breakthrough in combining hydrogen and nitrogen to form ammonia, and it further hastened the end of Chile's domination of the world market for chemical nitrogen (26). Many other ammonia synthesis processes have since been developed, but they differ from the Haber-Bosch technique only in the preparation and purification of the synthesis gas, the operating pressure of the synthesis unit, the design of the synthesis converter, and the method for recovering ammonia (44).

The major operations involved in manufacturing synthetic ammonia are gas preparation, carbon monoxide conversion, gas purification, and ammonia synthesis. Several variations of the gas preparation stage are available, but each variant converts the hydrocarbon feedstock and other production materials into a gas mixture containing hydrogen, nitrogen, and oxides of carbon. The most common method in the United States is the steam reforming process, which uses natural gas as the hydrocarbon feedstock. The natural gas (primarily methane) is desulfurized, preheated, and at 300-500 pounds per square inch (psi) is mixed with superheated steam in the primary reformer. The product gas from this stage consists of hydrogen, carbon monoxide, carbon dioxide, excess steam, and unconverted methane. It then passes to the secondary reformer where a controlled amount of air is added to reduce the unconverted methane and to provide sufficient nitrogen for a 3:1 hydrogen/nitrogen ratio in the synthesis makeup gas.

Through approximately 1952, natural gas reformers (for the gas preparation stage) were designed only for low-pressure operation. With improved fabrication techniques and alloys, modern reforming units can operate at much greater pressures. These developments have made ammonia production more economical by--

- . Conserving the pressure of incoming natural gas.
- . Eliminating the need for compressing the process gas in the purification state.
- . Reducing the size of equipment needed.
- . Reducing the power requirement for gas compression.
- . Recovering more waste heat.
- . Reducing the volume of required catalysts (54).

Although the essence of the gas preparation stage is the conversion of hydrocarbon and carbon monoxide to hydrogen, most of the remaining steps prior to synthesis, by itself, involve the removal of carbon oxides from what becomes the synthesis makeup gas. In the carbon monoxide conversion phase, the gas leaving the secondary reformer (approximately 11 percent carbon monoxide) is reacted with steam in the presence of a catalyst. Carbon dioxide and elemental hydrogen are formed. The reduction of the carbon oxides level in the premakeup gas is an essential stage in ammonia synthesis, as these compounds act as a poison to the catalyst in the actual synthesis stage.

In the first part of the gas purification step, carbon dioxide is removed from the gas stream. The most common processes use one of several solvents to "scrub" the gas--monoethanolamine (MEA), hot potassium carbonate, or Sulphinol. Although each solvent or solvent type has particular advantages and disadvantages, MEA scrubbing is among the more commonly used in the United States.

In the final portion of the gas purification step, the carbon oxide content of the synthesis makeup gas is reduced to less than 10 parts per million. This is accomplished by methanation, historically with absorption using a copper solution, or by washing using liquid nitrogen. Methanation is the process most often employed domestically, and it involves heating the gas stream to approximately 575 degrees F and passing the gas through a nickel-base catalyst. The carbon oxides react with hydrogen to form methane and water (44). Although most of the water is removed after the gas leaves the methanator, methane is not removed, as the methane does not damage the synthesis catalyst.

The last phase in the production of ammonia is synthesis itself. The extent of ammonia conversion depends on pressure, temperature, hydrogen-nitrogen ratio, methane concentration, space velocity, and catalyst activity. Equilibrium is favored by higher pressures and lower temperatures (54). Temperature control is an important element in this phase of production. As the reaction rate increases with higher catalyst temperatures, equilibrium yield decreases.

Modern ammonia plants are centered around closely related and integrated steps for gas generation, purification, and synthesis. These steps were often separate in older designs. In newer plants, the energy available within the process has been considered more closely in relation to the energy needed to operate the entire plant. Further, process conditions have been selected to make more efficient and economic use of machinery and equipment.

Some of the more important changes in plant design which evolved from the incorporation of these concepts are as follows (1):

- Complete redesign of the steam-generator system.
- Recovery of waste heat concurrent with economic selection of equipment.
- A substantial increase in reforming pressure, leading to high thermal efficiency and lower compression costs.
- Reduction in synthesis pressure to allow the use of centrifugal compressors in the synthesis cycle.
- Virtual elimination of electric power consumption by using a highly efficient energy cycle.

As a consequence, fuel required for reforming and power required for compression have declined (although total fuel use has increased slightly). Heat available from gases leaving the shift converter has increased (because of greater reformer pressure), and boiler feed water heat and low pressure steam have been made available to other parts of the plant by advances in the synthesis loop phase of production (30).

Through the fifties, most ammonia plants were organized as a series of parallel units or "trains," the largest of which had a design capacity of approximately 350 tons per day and each of which was driven by a reciprocating compressor. Plants

organized in this fashion could usually operate year round, responding readily to changes in market conditions by shutting down one or more trains when demand was low. The feasibility of smaller plants continued through the early sixties, as storage capacity was insufficient to hold the output from larger plants during offpeak periods (37). Consequently, the industry favored small plants serving small radius markets and incurring low distribution costs.

As the total market and inseason demand for ammonia continued to grow, advances were made in storage design and the capacities of storage units increased. Refrigerated vessels were successfully introduced, permitting the containment of ammonia at atmospheric pressure. Larger transport units could be used, and barge and ship movement of refrigerated ammonia became practical. A change in industry orientation began to occur--toward larger production plants operating at capacity year round, simultaneously supported by sufficient storage and distribution facilities.

The incorporation of this orientation toward larger plants into actual operations began in 1963 when the first domestic 600-ton-per-day single-train plant came on stream (39). The operation utilized centrifugal compressors in the synthesis loop, which, in conjunction with the increased pressure of the makeup gas leaving the reforming phase, facilitated the synthesis of ammonia at lower compression pressures than in reciprocating-type plants. Both plant investment and operating cost per ton of product declined, since a large proportion of both investment and operating costs of ammonia plants is associated with compressing the synthesis gas for the synthesis cycle and since the pressure in centrifugal compressors is 25 to 50 percent lower than in the reciprocating units. Two important qualifications are that centrifugal compressors are not economically feasible in plants with capacities of less than 600 tons per day and that the efficiency of a centrifugal-type plant drops rapidly at production rates below 70 percent of capacity (38).

As a result of the introduction and adoption of centrifugal compressors and other technological advances in ammonia production, the average capacity of operating plants has increased from 300 tons per day in 1964 to over 600 tons per day at present. Maximum single-train capacity has jumped from 600 tons per day in 1964 to nearly 1,800 tons per day in a Japanese plant. It has been estimated that a single-train plant can be constructed to produce 3,000 tons per day (52). However, the largest domestic single-train plant produces about 1,600 tons per day; that is at present the largest economically feasible operation.

Further technological advances will be made in the industry, although it is uncertain at this time where the point of diminishing returns to plant size will be. It is most likely that changes in the short run will involve refinements in current processes and fabrication techniques. Since energy costs represent a significant part of the total costs of ammonia production, engineering and design companies are devoting substantial time and money to research and development activities designed to improve energy efficiency in manufacturing. Other areas of plant operation and design receiving attention are gas generation, reformer tube metallurgy, recovery of low level heat, and improvement in shift conversion and synthesis catalysts.

Decisions on whether and where to build anhydrous ammonia plants depend on the expected availability and costs of natural gas. Depending on the age and size of plant, natural gas, even at a low cost of \$.50 per thousand cubic feet, may comprise from 30 to over 50 percent of total ammonia production cost. Consequently, the recent large increases in gas prices translate directly into higher costs to produce ammonia and indirectly into higher raw material (ammonia) costs for producing ammonia derivatives.

Although many hydrocarbons may be used as hydrogen sources for ammonia production, natural gas is preferred where supplies are available. Conversion among feedstocks is not a streamlining procedure, because it usually involves a complete redesign of the plant, depending on the synthesis process used. Steam reforming is amenable to either natural gas or naphtha feedstocks, and except for sulfur removal from naphtha in the prereformer phase of production, the production techniques are very similar.

Using fuel oils or coal as feedstocks requires a partial-oxidation process. This differs considerably from steam-reforming, as partial oxidation requires an air-separation plant to produce oxygen for the process. Overall capital costs are 1.5-2.25 times greater than those for steam reforming, and energy consumption is also higher.

A partial-oxidation plant using coal differs somewhat from one using fuel oil. The air-separation plant must be about 25 percent larger to provide additional oxygen necessary to gasify the coal. Additional plant equipment is required to grind and handle the coal as well as to remove and dispose of the ashes. As a consequence, a coal-based plant may cost 10-20 percent more to build than an oil-based operation.

Other feedstock alternatives have been considered, such as hydrogen from water in nuclear energy plants, but at present they are not economically feasible for ammonia producers. Natural gas remains preferable as the hydrogen feedstock followed by naphtha. Naphtha can be used in plants presently using natural gas with some conversion and a slight reduction in capacity. Capital costs for new naphtha plants are approximately 1.1-1.2 times greater than those for a similar-sized natural gas plant.

Although there are few feasible alternatives for natural gas as a feedstock, the rapid escalation of gas prices in the past 5 years and shortages of gas supplies to interstate pipelines have caused many producers to consider alternative fuels for other parts of plant operation. In a steam-reforming plant based solely on natural gas, an average of 33,000-38,000 cubic feet of natural gas are used per ton of ammonia produced. Of this volume, approximately 60 percent is for feedstock energy needs and 40 percent for nonfeedstock needs.

It is relatively simple to convert from natural gas to other fuels for firing plant reformers. The fuels must be of high quality (for example, naphtha, propane, or fuel oil). The metallurgical properties of reformer tubes currently being used would be adversely affected by fuels containing large amounts of heavy metals, sulfur, or ash. Premature tube failure would likely result (34).

Fuel oil prices have escalated significantly since the oil embargo in the midseventies. Although there has not been a widespread shift by ammonia producers to fuel oil, the rapid increase of natural gas costs and the likely continued escalation in the future have had an impact. Planned conversions by some ammonia manufacturers to fuel oil for heating indicate that they see these changes as one way to incorporate more flexibility into plant operations by reducing their vulnerability to natural gas curtailments. In addition, new plants are being developed to use fuel oil. As a consequence, the industry will have the capability of supplying some 27 percent of its nonfeedstock energy requirements with fuel oil in 1980, up from 7 percent in 1975.^{5/}

^{5/} Estimate based on (8).

Ultimately, the feasibility of conversion from natural gas to alternative nonfeedstock fuels depends on relative prices, the costs of conversion, and foreseen longrun supplies of the materials. Ammonia manufactured for fertilizer consumed approximately 2.2 percent of the total natural gas used for all purposes in the United States in 1973. Approximately half of the U.S. ammonia capacity is based on interstate gas, the price of which is regulated by the Federal Government. Intrastate gas is not subject to Federal regulation, and its price has increased significantly in the past 5 years. This price differential has led to the development and sale of most new natural gas within the producing State and consequent curtailments of supplies to the interstate pipelines.

Size of plant and economies of scale.--A major determinant of the farm price of ammonia and the quantities of ammonia and ammonia-based fertilizers used is the cost of producing and distributing the product. The trends in ammonia production costs depend not only on the types of plants in existence at a particular time but also on changes in plant sizes, technology, locations, energy costs, and the prices of industrial goods used in building these operations.

The first U.S. synthetic ammonia plant had an initial rated annual capacity of 10,000 tons of materials. Output was eventually increased to 18,000 tons of material per year. The first large-scale plant started in 1926, with an annual rated capacity of approximately 60,000 tons. By 1929, another facility was capable of producing 95,000 tons of ammonia per year (23). By 1934, 8 of the 12 plants built in the United States were operating with a collective rated capacity of 415,000 tons per year (or an average of nearly 52,000 tons in each plant) (23). Nearly all of the ammonia produced was used for industrial purposes rather than for fertilizer.

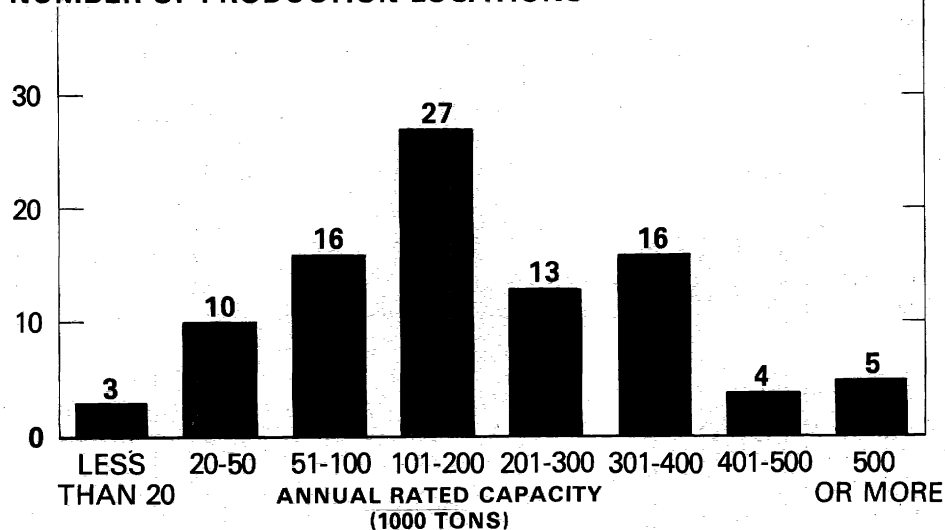
The U.S. Government became heavily involved in construction of synthetic ammonia capacity during World War II to insure sufficient supplies of nitrogen for munitions. There were 10 Government plants in 1945 with a combined annual rated capacity of 975,000 tons of ammonia. By 1949, six of these plants had been sold or leased to private industry. The Korean War brought about the next surge in ammonia capacity buildup. Entry was encouraged by liberalization of the tax laws and ammonia's increasing popularity as a fertilizer. By 1958, there were 57 plants producing ammonia in the continental United States. The average rated annual capacity of each operation was approximately 90,000 tons of materials (41).

Although average plant size had increased significantly even before the advent and widespread incorporation of the centrifugal compressor into ammonia production facilities, the greatest increases have occurred since the midsixties. By that time, industry orientation had shifted from the "small plant-small market area" philosophy of the fifties to a preference for large plants with adequate downstream storage and distribution capabilities. In 1964, the average annual rated capacity of operating plants was 102,000 tons (material weight) with a range of 11,000 to 400,000 tons (49).

Currently, the greatest proportion of operations produces approximately 200,000 tons of material annually or, assuming 340 days of operation per year, 600 tons per day (fig. 9 and app. table 2). Many of these plants began operating soon after the centrifugal compressor was successfully incorporated into plant design in the midsixties. Several plants are producing 301,000-400,000 tons annually. The most common plant size in this group produces 340,000 tons per year or 1,000 tons per day. Many technical and cost comparisons are based on this plant. (Many plants with rated capacities from 1,000 to 1,200 tons per day are refinements of the 1,000-ton-per-day operation.) Of the nine plants shown with individual capacities in excess of 400,000 tons per year, the largest produces nearly 700,000 tons, and it incorporates two

DISTRIBUTION OF ANHYDROUS AMMONIA PLANT SIZES, 1976

NUMBER OF PRODUCTION LOCATIONS



USDA

NEG. ERS 2669-77 (1)

Figure 9

trains having respective capacities of over 600 tons and approximately 1,500 tons per day. Many of the plants expected to begin operating in the next 4 years (by 1980) have rated capacities of from 1,200 to 1,500 tons per day.

Refinements have been made in the smaller capacity plants, and the plants remain a significant component of the industry. In addition to plant size and capital costs, the prime determinants affecting the cost of producing ammonia are raw materials and utilities prices. Since these costs are dependent upon location, smaller ammonia plants continue to be viable in many parts of the country. The output of a large capacity plant must be supported by a storage and transportation system adequate to accommodate the product volume. The logistics problems and capital requirements are often considerably less complex for a small plant.

Table 11 contains representative budgets for three sizes of natural gas steam-reforming plants assumed to have started operating in mid-1973. Both the 600-ton and 1,000-ton-per-day plants use steam-driven centrifugal compressors. The 400-ton per day plant uses motor-driven reciprocating compressors. Monoethanolamine (MEA) is used for carbon dioxide removal. Costs per ton are based on the assumption that each plant is operating at design capacity. Other assumptions are shown in appendix table 3.

With the exception of natural gas, average cost declines with size of plant for each cost category. Most noticeable in the variable costs is electricity for which centrifugal-type plants are nearly self-sufficient (hence, the marked decline in power requirements from the 400-ton-per-day plant). There is also a significant reduction in labor cost per ton as plant size increases. Each plant requires five

operating laborers per shift, and their costs are spread over larger volumes of output in the 600-ton and 1,000-ton-per-day plants.

Average fixed costs drop sharply between the 400-ton and 600-ton-per-day plants and less sharply between the 600-ton and 1,000-ton-per-day operations. The shift in compressor and turbine types between the 400-ton and 600-ton units accounts for the major decline. Plant investment and working capital per ton of ammonia also drop significantly. These declines are responsible for the average fixed costs behavior among plant sizes.

The budgets presented are assumed to be for plants which began operating in 1973. Since that time, plant construction costs have escalated dramatically--in some cases more than doubling between 1973 and early in 1976. There are many reasons for the increases. Among the most important are the rising costs of hardware (for example, steel, pipe, reaction vessels), wage rates, and engineering (24). Most new plant contracts are written to reflect costs actually incurred plus the engineering/construction fee. As materials costs have risen, so have the total costs of the plants under construction. Current battery limits costs for a 1,000-ton-per-day plant are approximately \$50 million.^{6/}

Ammonia plants have been and are being built with capacities exceeding 1,000 tons per day. At present, the capital costs for these facilities are approximately proportional to a 1,000-ton-per-day plant. In some cases, the units are streamlined, "debottlenecked" versions of the more standard 1,000-ton units. As the 1,250-ton and larger units are further developed, the attendant compressors, turbines, and other specialized equipment will become more standardized. Assuming the rate of inflation in plant construction costs is equal among plant sizes, average capital costs per ton of product should decline for larger units. At present, it appears that overall cost reductions per ton of ammonia become relatively insignificant as plant size exceeds 2,000 tons per day (13).

Effects of increased natural gas prices on production costs.--Each budget shown in table 11 assumes a natural gas cost of \$0.50 per thousand cubic feet. Operating budgets are shown in table 12 for a 1,000-ton-per-day unit assumed to be paying \$1.00 and \$1.50 per thousand cubic feet of gas. The effects of the higher gas prices are reflected in the gas costs of producing ammonia, interest on working capital, and return on investment. All input-output coefficients and all other costs are identical to those shown in table 11.

Urea

The first isolation of urea as a compound was from human urine in 1773. It was first produced in 1828 from an inorganic substance known as ammonium cyanate and from ammonium carbamate in 1868. Industrial production of urea began in Canada in the twenties and was based on nitrolime. The product was synthesized from ammonia and carbon dioxide in Germany in 1922. This process became the dominant production method by the midthirties. Commercial production in the United States began in 1932 (32).

^{6/} The approximate "overnight" cost is for a plant currently becoming operational (contracted 3-4 years earlier).

Manufacturing processes and technology.--Many different commercial urea processes are available. Each relies on the combination of liquid ammonia and carbon dioxide to form ammonium carbamate which is then decomposed into urea and water. The synthesis is reversible, and conversion is affected by temperature, pressure, feed composition, and reaction time. In general, the reaction is favored by high temperatures in the presence of high pressures to prevent the reactants from passing to a gaseous state (33). The reaction of ammonia and carbon dioxide is highly exothermic, and temperature must be closely controlled. Often, excess ammonia is maintained in the reactor for this purpose and to increase ammonium carbamate formation.

All commercial urea processes today are based on the reaction of ammonia and carbon dioxide. Only part of the ammonia is converted, and this condition gives rise to commercial variants for urea production. In general, these processes differ by their methods for handling unreacted ammonia, in how much of the ammonia is recycled (in recycle-type processes), and in how the product (urea) is finished. All require abundant supplies of ammonia and carbon dioxide. Consequently, U.S. urea plants are located adjacent to ammonia plants which provide both feedstocks necessary for urea production--ammonia and carbon dioxide.

The three basic urea processes used are once-through, partial recycle, and total recycle. Each has several commercial variations. The once-through system is the most simple and least expensive in terms of investment and operating costs. Ammonia and carbon dioxide are pumped into the urea reactor at 2,500 to 3,000 psi. The reactor is maintained at approximately 365 degrees F with excess ammonia. Approximately 35 and 75 percent of the ammonia and carbon dioxide are driven off by heating the effluent solution in carbamate strippers. The reactor effluent contains approximately 80 percent urea after stripping (54).

Urea can be produced economically in a once-through system if several conditions are met (33):

- . The unreacted ammonia can be utilized elsewhere in the production complex, such as in the manufacture of ammonium nitrate, nitric acid, or ammonium sulfate.
- . Carbon dioxide is available in abundant supplies at low cost.
- . Excess ammonia levels are held as low as possible if the unreacted ammonia is not easily used elsewhere on site. The heat produced in the reaction must be removed, sometimes by methods other than that depending on excess ammonia.

Few urea plants in the United States use a once-through process (relative to the number using recycle processes). Most plants that use a once-through system are located adjacent to nitric acid and ammonium nitrate production facilities, with the combined output used to make nitrogen solutions. In the domestic once-through plants, total ammonia efficiency ranges from 44 to 60 percent (3).

Partial recycle techniques (used in fewer than five U.S. production facilities) may be used when higher ammonia efficiency is desired or when available production lines cannot accommodate the excess ammonia from a once-through process. Parts of the unreacted ammonia and carbon dioxide are recycled to the urea reactor and their levels accordingly reduced. Any proportion of the unreacted ammonia can be recycled. Generally, the amount of ammonia that must be used in some other process is reduced to approximately 15 percent of that from a comparable once-through operation (54).

In a total recycle process, the unreacted ammonia-carbon dioxide mixture is recycled to the urea reactor, making unnecessary the colocation of the urea plant with other process lines to utilize the excess chemicals. Total recycle plants are the most flexible among the three types and are favored by most producers.

Two general types of total-recycle techniques are in use today. The gas-separation process involves the treatment of the ammonia-carbon dioxide mixture from the carbamate stripper with liquid that preferentially absorbs one of the gases while leaving the second in its gaseous phase. The latter is recompressed and recycled to the urea reactor. The absorbed gas is desorbed and recycled separately to the reactor. In the second technique, called the carbamate-solution recycle process, all unreacted ammonia and carbon dioxide are recycled to the urea reactor as ammonium carbamate solution (54). Most U.S. urea plants incorporate total recycle processes. Overall ammonia efficiency ranges from 85 percent to more than 95 percent.

Urea plants also vary by the method employed to finish the product. The urea produced in the synthesis portion of an operation is approximately 70-80 percent pure, although the exact proportion is dependent upon the amount of recycling. The solution leaving the system may be used in liquid form or, with additional concentration, as a solid. The most common solid forms are prills and granules. In 1975, 48 percent was in the form of prills, and 22 percent in granules. Most of the announced plant expansions through 1980 are for solid products with 55 percent for granular forms (3). Granular urea has become especially popular with bulk blenders.

Size of plant and economies of scale.--The annual design capacities of U.S. urea plants range from less than 200,000 tons to over 400,000 tons of 100-percent urea (app. table 4). Assuming 340 production days per year, the annual capacities represent approximately 50 tons and over 1,100 tons per day. The average U.S. plant produces approximately 120,000 tons per year, or about 350 tons per day.

Representative investment and operating cost budgets are presented in table 13 for three sizes of urea plants (300, 600, and 1,000 tons per day). Costs are based on published budgets, consultations with industry representatives regarding current conditions, and the assumptions in appendix table 3. Each plant is assumed to have started operating in 1973 and employs a total recycle process based on ammonium carbamate solution. Each plant produces prills and is assumed to be colocated with an ammonia plant, thus incurring no charge for carbon dioxide.

Similar to the situation for other derivative fertilizers, the total production cost for urea depends significantly on the price of ammonia and the fixed plant costs. A constant input coefficient is assumed for ammonia which causes equal ammonia costs per ton of urea produced. Some cost variation is possible, based on the size of plant providing ammonia. In addition, there may be some variation in raw materials requirement per ton of urea with different plant sizes, but these differences are slight.

Nitric Acid

Nitric acid is an important intermediate product in the fertilizer industry, as it is used to produce ammonium nitrate. It is also used to produce less extensively used fertilizer materials, such as potassium nitrate, ammonium nitrate sulfate, ammonium nitrate phosphate, and calcium nitrate.

Manufacturing processes and technology.--The primary method used to manufacture nitric acid in the United States prior to the twenties was by reacting Chilean sodium

nitrate with sulfuric acid. A small amount of nitric acid had been produced in Europe early in the 1900's by passing air through an electric arc and recovering the oxidized nitrogen through a water absorption system. The low oxide yield and enormous electrical requirements for this process made it unfeasible.

With the greater availability of synthetic nitrogen as a result of the Haber-Bosch ammonia process, ammonia oxidation became the dominant U.S. method for acid production. Described in France in 1839 and developed in Germany in 1902, the ammonia oxidation process was first incorporated in a U.S. nitric acid plant in 1916 (9, 48). Ammonia oxidation plants proliferated in the forties as a result of expanded demand for explosives during World War II. With the end of the war, the greater capacity continued to be used, as the demand for ammonium nitrate fertilizer replaced that for explosives.

Nitric acid production involves the oxidation of ammonia through nitrous oxide to nitrogen dioxide, which is subsequently absorbed in water. In the United States, there are essentially two manufacturing processes used for oxidation and absorption. The primary feature differentiating the processes is the use of temperature and pressure in each of the reactions. In the first process (the simpler to operate), oxidation and absorption take place at atmospheric pressure. In the second and more commonly used process, oxidation and absorption occur under pressures of 60-100 psi.

Efficiency of ammonia oxidation is inversely related to pressure. For any given pressure, conversion efficiency may be optimized by application of appropriate temperatures (21). More generally, the efficiency of ammonia use is influenced by temperature, pressure, composition of feed stream, contact time, and the state of catalyst activity (48).

In contrast to oxidation, absorption efficiency is maximized under conditions of maximum pressure and the lowest possible temperature. The rate of oxide absorption increases with pressure. It is possible under these conditions to produce a more concentrated final product. Highly concentrated acid is required for the production of many industrial products, including explosives. This makes necessary the use of additional equipment in acid manufacture. Conversely, weaker acid (from 55 to 60 percent HNO_3) can be used for ammonium nitrate production.

Although the most common type of U.S. operation uses 60-100 psi pressures in both oxidation and absorption, the selection of a process for a particular situation depends on many factors, including the costs of ammonia and electrical power and the availability of capital. High pressure operation permits the use of smaller plant units for given levels of output and greater efficiency of oxide absorption. This is at the cost of greater catalyst losses, higher power requirements, and a slight reduction in overall nitrogen conversion efficiency. Further, maintenance charges are somewhat higher in a high-pressure plant. Where ammonia and power costs are high, low-pressure oxidation and medium- or high-pressure absorption systems may be preferable. In other cases where capital funds may be the primary limiting constraint, high rates of return and rapid capital writeoff given by a high pressure system may be desired. The final choice of process type is a function not only of technological factors but also of financial and accounting considerations (54).

Alternative methods have been developed for producing nitric acid. One, called the Wisconsin Process, was patented in the thirties and further developed by private industry and the U.S. Government from 1940 to 1953 (9). A mixture of nitrogen and oxygen or air is heated to approximately 4,000 degrees F to form nitrogen oxides. These oxides are cooled and absorbed in water. At present, the Wisconsin technique is not considered feasible for commercial acid production because of high operating costs.

Two other processes have been developed but offer no immediate commercial promise. The first involves the joint production of electricity and nitrogen oxides in magneto-hydrodynamic generators. In the second, nitrogen is fixed from the atmosphere by irradiating compressed air in an atomic reactor. Because of high energy costs neither process is currently feasible (9).

Size of plant and economies of scale.--The annual design capacities of operating U.S. nitric acid plants range from less than 10,000 tons to over 400,000 tons (app. table 5). Assuming 340 production days per year, the annual capacities are approximately 50 tons and over 1,175 tons per day. The average U.S. plant has a design capacity of 121,000 tons per year, or slightly over 350 tons per day (51).

Representative operating and investment cost budgets for three plant sizes are presented in table 14. These figures are based on compilations and updating of previously published data, consultations with industry representatives, and the assumptions listed in appendix table 3. The three plant sizes shown produce 250, 400, and 800 tons of nitric acid (100 percent HNO₃ equivalent) per day using high pressure for both the oxidation and absorption phases of manufacture.

Economies of scale are evident throughout the range of plant sizes considered. This is a function of declining capital costs per ton in the larger plants. All other input-output coefficients are assumed invariant across plant size. Sharp declines in average fixed costs and average return on investment are responsible for the decline shown.

Ammonium Nitrate

Commercial U.S. production of ammonium nitrate is based on neutralization of ammonia and nitric acid in the presence of water. The reaction is exothermic, and the heat is sufficient to evaporate the water and concentrate the resultant compound to approximately 83 percent. This solution crystallizes at 71 degrees C (160 degrees F) and must be stored in heated tanks.

Ammonium nitrate has been a popular nitrogenous fertilizer worldwide, despite its physical and chemical properties. In its solid form, the compound is quite hygroscopic and susceptible to caking. This property led to the utilization of moisture-proof bags (for holding the product) and of different finishing methods. Although not a serious problem in the fertilizer-grade product, ammonium nitrate is subject to thermal decomposition, especially in the presence of certain impurities. The tendency toward decomposition under heat makes the product liable to detonation (43).

Manufacturing processes and technology.--Although all fertilizer-grade ammonium nitrate produced in the United States is based on neutralization of nitric acid and anhydrous ammonia, the hygroscopicity of the solid product has led to the evolution of different methods for finishing it. The most common are prilling, granulation, melt processes, crystallization, and graining. Over 90 percent of solid ammonium nitrate produced in the United States is prilled, and nearly 7 percent is granulated. Less than 2 percent is produced in either grain or crystal form (2).

Today's prilling facilities are quite similar to the initial operations built in the forties. Prilling involves concentrating the solution from a neutralizer to 96 to 99 percent ammonium nitrate. Then, the liquid is pumped to and sprayed from the top of a tower. As the product descends through a rising stream of air, it solidifies into small spheres or prills. The sphere or prill sizes depend on the

tower height, air temperature, and airflow rate (42). The solid product is recovered from the bottom of the prilling tower and dried, cooled, and coated.

The primary granulation method employed in the United States uses rotary drums. Following granulation of the concentrated solution from the neutralizer, the product is partly dried by latent heat of crystallization. Final drying, cooling, and hardening is usually accomplished in airswept rotary drums, followed by coating, and, where applicable, bagging (54). A modification of this technique, called the Sphero-dizer granulation process, reportedly allows the production of granules with such a low moisture content that coating or other conditioning is unnecessary (2).

Size of plant and economies of scale.--The period of greatest technological advance in ammonium nitrate fertilizer production was from 1943, when it was first produced in solid form in two U.S. plants, to early in the sixties, at which time ammonium nitrate was beginning to lose ground to higher-analysis materials. During that period and even since, there have been several modifications to the prilling plant design, increases in plant size, and declines in labor requirements per ton of product.

The daily design capacity of operating plants at the end of 1975 ranged from less than 50 tons to over 1,000 tons (app. table 6). Many of the production units are located at the sites housing manufacturing facilities for anhydrous ammonia and nitric acid, the primary raw materials required to produce ammonium nitrate. New facilities, which are scheduled for operation late in 1976 and through 1980, range in size from approximately 250 tons to 1,100 tons per day.

Representative budgets for three sizes of prilling operations assumed to have started operating in 1973 are presented in table 15, based on the assumptions in appendix table 3. Each operation is assumed to be colocated with anhydrous ammonia and nitric acid plants (offsite facilities are shared and for the ammonium nitrate plant are estimated as 15 percent of investment). The input-output coefficients shown are compiled from several different sources. The plant investment and working capital figures are based on updated costs from previous budgets.

Production cost declines with increasing plant size, though not so markedly as for synthetic ammonia plants. The reduction in average fixed costs is mainly responsible for the decline, although labor requirements also drop slightly. The overall cost of producing ammonium nitrate depends primarily on the costs of nitric acid and anhydrous ammonia, the two raw production materials. Should natural gas and, consequently, ammonia become more expensive, the cost of producing ammonium nitrate will increase.

Ammonium Phosphates

A variety of ammonium phosphate grades can be produced. The differences depend upon the type of phosphoric acid utilized and the proportions of monoammonium phosphate (MAP) and diammonium phosphate (DAP) incorporated in the compounds. Products based on wet-process acid are usually less hygroscopic and have better storage characteristics than those made from furnace acid (42). Under appropriate conditions, the degree of ammoniation in the reaction may be regulated to yield straight MAP or DAP, or a mixture of the two (54).

Manufacturing processes and technology.--Solid ammonium phosphates are produced in granular and crystalline form. The primary granulation processes employed are "slurry ammoniation" and "slurry and solids ammoniation." Until the early-to-mid-sixties, slurry granulation was used almost exclusively to produce ammonium phosphate products. In that process, phosphoric acid was neutralized in a series of

ammoniation tanks where some of the water was evaporated by reaction heat. The desired product grade was produced by controlling the degree of ammoniation. The slurry from the reaction tanks flowed to a "blunger" (a twin-shaft pugmill or rotating cylinder) where it was mixed with dry recycled product and, when desired, other materials to produce the fertilizer analysis desired. The primary ammonium phosphate product manufactured using this process was 16-48-0 (44).

Early in the sixties, the Tennessee Valley Authority (TVA) patented a second ammonium phosphate granulation process in which both slurry and solids are ammoniated. Phosphoric acid is mixed with ammonia in a preneutralizer, and heat from the ammonia-acid reaction is utilized to evaporate water in the slurry. Less drying equipment is required than in slurry-ammoniation methods (54). The slurry flows from the preneutralizer to a granulator where it is spread over a bed of recycled product and further ammoniated to the desired $\text{NH}_3:\text{H}_3\text{PO}_4$ mole level of 2.0. The slurry solidifies quickly, and a relatively low recycle ratio is feasible. Excess ammonia must be fed to the granulator to attain the desired degree of ammoniation. The excess ammonia mixed with water evaporated in the granulator moves to a scrubber in which the ammonia is recovered by absorption in the inflowing phosphoric acid (42).

Nearly all solid ammonium phosphates used in this country are based on granulation. Approximately 80 percent are produced using the TVA process (5). The two-stage ammoniation in the TVA process provides a low water content in the preneutralizer slurry. This allows granulation at a low recycle rate and requires less drying equipment. Further, the system is as flexible as other production methods in allowing the incorporation of other materials, such as sulfuric acid, ammonia-ammonium nitrate solutions, and potash in the process streams.

In the pan granulation process, the desired reactants (ammonia and sulfuric acid, nitric acid, or phosphoric acid) pass through a first-stage neutralizer, an evaporator, and a second-stage neutralizer where additional ammonia is injected. The concentrated slurry passes from the second-stage neutralizer to a cascading bed of recycled solids on an inclined rotating pan. The resultant granular product is dried and sized. The process is highly versatile, and it may be used to produce not only granular ammonium phosphates but also ammonium nitrate, ammonium sulfate, and urea (63).

The pipe-cross reactor is one of the newest developments in ammonium phosphate production. It was developed by the TVA and has been used successfully to produce MAP as well as several N-P-K mixtures. The technique basically involves the prereacting of phosphoric and sulfuric acids with ammonia in equipment that is considerably simpler than the preneutralizer incorporated in the TVA slurry granulation process. There are several advantages, including

- . The ability to use larger proportions of both phosphoric and sulfuric acids than in the preneutralizer.
- . The saving of fuel, as the reaction generates sufficient heat to dry the product.
- . Savings of capital, as investment costs are much lower than for a preneutralizer.
- . The ease of operating the cross-pipe reactor.

Relatively small amounts of crystalline ammonium phosphates are produced primarily by coke producers and industrial phosphate firms, with most of the output consumed in nonfertilizer markets. In this process, gases from the coke ovens are

cleaned and passed through a saturator in which the contained ammonia reacts with industrial grade phosphoric acid. As the solution becomes saturated, ammonium phosphates crystallize and are removed by centrifuges and dried (54). Furnace-process phosphoric acid (produced in small amounts and at greater cost relative to the wet-process product) is required for crystallization, because iron, aluminum compounds, and other impurities found in wet-process acid inhibit crystallization (43). Conversion from production of ammonium sulfate to ammonium phosphates is relatively easy and requires only additional heat to evaporate larger amounts of water introduced with phosphoric acid (42).

Processes for producing powder MAP have been developed in the United Kingdom and other countries. The processes usually incorporate the spray drying of the product into a powder form which is used primarily for wet-mix complete fertilizers. Some processes offer higher ammonia efficiency than DAP granulation equipment (5). Most commercially available forms of powder MAP are amenable to further ammoniation in ammonia granulators. This is a feasible practice when there is an abundant low-priced supply of ammonia (16).

Size of plant and economies of scale.--Each ammonium phosphate plant has considerable flexibility in the grades of product it produces. For purposes of illustration, the plants compared (table 16) produce granular DAP, specifically grade 18-46-0. Each plant is associated with a wet-process phosphoric acid facility (that is, acid is "captive"). The TVA slurry-solids ammoniation process is employed. Ammonia recovery is 95 percent, and the phosphoric acid used has a 54-percent P2O5 content. The plants produce 500, 975, and 1,450 tons of DAP per day, corresponding to the range of U.S. plants currently operating (app. table 7). Offsite facilities are shared with the associated phosphoric acid plant, and offsite costs associated with DAP alone are assumed to be 20 percent of the DAP battery limits investment. The phosphoric acid plant has sufficient capacity to supply the acid needed for the largest DAP plant. The same size of acid plant is associated with the smaller DAP plants. Investment costs are based on plants which began operating in 1973. Other assumptions are as shown in appendix table 3.

Average total production cost declines slightly with increases in plant size because of the declines in average fixed costs per ton of product. Variations in raw material costs would directly affect their contribution to production cost and indirectly affect the working capital account. If a smaller phosphoric acid plant is associated with the smaller DAP plants, average production costs would be somewhat higher for those units.

Ammonium Sulfate

Approximately 15 domestic plants produce synthetic ammonium sulfate, which is based on the neutralization of ammonia with sulfuric acid and removal of water from the solution. The solution is then crystallized for fertilizer use.

Little new synthetic product capacity has been added in the United States since the midsixties. Nonetheless, the product is used in many mixed fertilizers and as a separate fertilizer in some parts of the country, especially the Mountain and Pacific States (States in those regions collectively accounted for 69 percent of total straight product consumed domestically in the year ending on June 30, 1976) (62).

No relatively new synthetic product plants are being planned, and none are anticipated through 1980. So, investment and operating costs budgets similar to those presented for other nitrogenous fertilizers are not included for ammonium sulfate.

Nitrogen Solutions

Nitrogen solutions (aqueous solutions of ammonia, ammonium nitrate, or urea, separate or in combination) may be used in manufacturing liquid or in dry mixed fertilizers or applied directly. They were first commercially produced in the thirties, and their use was given strong impetus by the development of the synthetic ammonia industry in the fifties and sixties. Although nitrogen solution manufacturing can be performed as an independent process, most domestic products are manufactured as an accessory part of ammonia, ammonium nitrate, or urea process lines. In such plants, nitrogen solutions may be produced quite easily by drawing out the process liquor and adjusting its concentration (54). Of the 29 U.S. companies having solutions capacity on January 1, 1976, all but 2 had captive sources of all three nitrogen components used in solutions production (11).

There are certain advantages in using nitrogen solutions rather than solid fertilizer products. Although the 28-32 percent nitrogen content of nonpressure solutions is lower than ammonium nitrate and urea, there are no problems with caking and dusting with solutions. The solutions are more soluble than solids, thus facilitating incorporation in irrigation water. Further, it is relatively easy to incorporate herbicides and other chemicals into solutions, and there may consequently be some labor savings by using the solutions.

Solutions may be classified as "pressure" or "nonpressure," which relates to the container type needed for storage. Products containing ammonia must usually be pressurized to avoid volatilization of ammonia. In addition, ammoniacal solutions, except for aqua ammonia, are primarily used for manufacturing mixed fertilizers, although some are used for direct application in original or dilute concentration. Solutions of urea or ammonium nitrate (with no ammonia), or both, do not have vapor pressure and do not require pressurized storage (54). Approximately 56 percent of the 1974 solutions production (based on a nitrogen content of 100 percent) were nonpressure solutions containing no free ammonia (38).

Comparative budgets are not presented for nitrogen solutions plants. The costs of these operations depend directly on the sizes, ages, and costs of the anhydrous ammonia, urea, and ammonium nitrate facilities which are needed to produce the materials used in solutions. The solutions are formulations, as the basic products do not react chemically. Consequently, the solutions mixing facility itself is relatively simple, and capital costs are low. However, the capital costs for the anhydrous ammonia, urea, and ammonium nitrate plants are quite high. So, it is necessary to consider these costs as well as those of the solutions mixing facility in estimating the total costs for producing nitrogen solutions.

PHOSPHATE FERTILIZER SECTOR

The phosphate fertilizer industry includes all producers and processors of phosphate rock, phosphoric acid, phosphatic fertilizers, and sulfuric acid. Phosphate rock and sulfur (sulfur is incorporated in sulfuric acid and used in that form in the production of phosphatic fertilizers) are the major sources for all fertilizers carrying phosphate (P2O5). Nearly 80 percent of the U.S. phosphate rock production and 55 percent of its sulfuric acid are used to produce fertilizers.

Production, Product Flow, and Consumption

The major phosphatic fertilizer materials used in this country are phosphoric acid, normal and concentrated superphosphate, ammonium phosphates, and nitrogen-phosphorous-potassium (N-P-K) mixtures. Although the total production of phosphatic material has increased over time, the composition of production among these major products has changed considerably. In the last 20 years, the production of phosphoric acid, ammonium phosphates, and, to a lesser extent, concentrated superphosphate has increased. The production of normal superphosphate, a relatively lower analysis product, has declined.

Phosphoric acid is an important intermediate means for incorporating inorganic phosphorous values into a variety of products. The primary acid uses are production of chemical products for agriculture and acidulation of phosphate rock for orthophosphate products. Besides being the most important phosphorous-carrying product for use in chemical fertilizers, phosphoric acid is used in producing phosphatic feed supplements. Not all phosphoric acid is used in agriculture, however, as substantial quantities of higher purity product are used in industry.

Several processes may be used to produce phosphoric acid. The most common in the United States is the "wet process," which is the acidulation of phosphate rock with sulfuric acid. (Others are the "furnace process," involving the smelting of phosphate rock with coke and silica in an electric furnace, and a process in which elemental phosphorous is burned and converted to phosphoric acid.) Raw wet-process acid usually contains 28-30 percent P2O5 and must be concentrated before it is used to produce ammonium phosphates or the superphosphates. Diammonium phosphate production requires an acid of 40-45 percent P2O5 content which is generally a blend of 28-30 percent production acid and 50-54 percent evaporator acid. An acid of either 40-45 percent or 50-54 percent may be used to produce concentrated superphosphate, depending on the type of product desired.

Sulfuric acid is an important component of the phosphate sector, as it is used directly or indirectly in the production of most phosphatic fertilizer materials. Among mineral acids manufactured in the United States, sulfuric acid is produced in the greatest volume and is used extensively throughout industry as well as in fertilizer production. Although there are many possible sulfur sources for acid, the most common source used domestically is new sulfur. Purified molten sulfur is oxidized with dry air under pressure to yield sulfur dioxide. Sulfur dioxide is catalytically oxidized with vanadium pentoxide. The resultant sulfur trioxide is absorbed in water to produce sulfuric acid.

Sulfuric acid is used directly in the production of normal superphosphate and orthophosphoric acid. Normal superphosphate, 18-20 percent P2O5, is produced by

mixing 68-80 percent (H_2SO_4) sulfuric acid with 31-35 percent P205 phosphate rock and allowing the reactant to cure. Higher acid concentrations are typically used with lower rock grades to obtain high product analysis.

Concentrated superphosphate has a P205 content of 42-50 percent. It is made in both granular and fine-particle sizes by acidulating phosphate rock with phosphoric acid and allowing the product to cure. Approximately 25-30 percent of the product's P205 content evolves from the feed phosphate rock, and the remainder from acid. There is some variation in the proportions because of differences in the concentrations of the respective inputs. Concentrated superphosphate is used both as a direct application material and as a component of mixed fertilizers (that is, blended with other nutrient carriers, such as urea, ammonium nitrate, and potash).

Many producers utilize "high-sludge" phosphoric acids generated from other phosphate operations to produce concentrated superphosphate and ammonium phosphates. Continued production of high-sludge acids is likely as a result of increased manufacturing of merchant product and gradual reductions in the quality of phosphate rock. It is also likely that there will be continued manufacturing incentives to produce concentrated superphosphate.

Ammonium phosphates are inorganic salts derived from the reaction between ammonia and phosphoric acid. They are produced as solids and fluids and contain P205 values in orthophosphate (usually solid) and polyphosphate (usually fluid) forms. Ninety-nine percent of the solid ammonium orthophosphate-based products are used in fertilizers, either as direct-application materials or in complete mixed fertilizers.

All fertilizer ammonium phosphates produced in the United States are based on wet-process phosphoric acid. Only two of the five known ammonium orthophosphate salts have much commercial importance--monoammonium (MAP) and diammonium phosphate (DAP). The most common commercial grades of MAP are 11-48-0, 11-55-0, and 13-52-0, which are sometimes used in combination with ammonium sulfate to produce other grades of product.

Nearly 80 percent of the U.S. production of ammonium phosphates (on a tons of product basis) is in the form of diammonium phosphate. The most common commercial grade is 18-46-0, although small amounts of 16-48-0 are also used as fertilizer. Virtually all of the fertilizer grade 18-46-0 is produced using wet-process phosphoric acid. Small amounts of the product are manufactured using defluorinated wet-process acid and used in cattle feed.

The amount of phosphate rock utilized in fertilizer materials in the United States increased from 37.5 million tons (carrying 11.6 million tons of P205) in 1969/70 to 48.1 million tons (carrying 14.8 million tons of P205) in 1974/75 (table 17). Wet-process phosphoric acid was responsible for the greatest proportion of the increase. The rock utilized for that product more than doubled from 10.0 million to 25.4 million tons. As a result, 53 percent of the total P205 content of phosphate rock used or sold by producers in 1974/75 was incorporated in wet-process acid. Conversely, the amounts of rock used for electric furnace acid and normal and concentrated superphosphate fell significantly in those 5 years. In total, 71 percent of the rock sold or used in 1974/75 was utilized in the domestic manufacture of phosphatic fertilizers, and the remaining 29 percent was exported.

The greatest proportion of wet process phosphoric acid is used to manufacture ammonium phosphates. In 1974/75, these products utilized 50 percent of the P205 value in wet-process acid (table 18). Solid ammonium phosphates accounted for 39 percent of that 50 percent, and fluids, the remaining 11 percent. Concentrated superphosphate and other solid mixed fertilizers and liquid fertilizers used nearly all the rest of the acid, although a small amount was applied directly to the soil.

Ammonium phosphates are the most important carriers of phosphate values in terms of the total domestic supply of P2O5. They accounted for 39 percent of P2O5 tonnage produced domestically in 1975 (table 19). Nearly 33 percent of domestic P2O5 production was in normal, enriched, and concentrated superphosphates, and the remaining 28 percent was in other products. But substantial amounts of ammonium phosphates and concentrated superphosphate were exported. Consequently, ammonium phosphates contributed about 33 percent and concentrated superphosphate about 22 percent of net domestic P2O5 supply.

Imports of phosphate rock are nearly zero, except for small quantities of low-fluorine product. Exports of rock are sizable as available supply is much larger than demand. Most of the U.S. exports are from Florida and North Carolina, which have convenient access to water transportation. It has been estimated that approximately a third of the North Carolina and Florida rock is exported.

Prices

The prices of phosphate fertilizers have followed a course similar to those of other fertilizer materials. The prices of phosphate rock increased dramatically from their 1966-72 levels to record highs in 1975 and 1976. There was virtually no change in price between 1966 and 1972 (table 20).

In 1973, however, there were accelerated demands for all fertilizer materials, including phosphate rock, and rock inventories dropped significantly. Prices increased rapidly from \$23 per ton in December 1973 to \$34 in September 1974 and to a maximum of \$52 in February 1975. Relatedly, the value of phosphate rock (f.o.b. mine) more than quadrupled from its 1972 level of \$5.10 per ton to \$22.67 in 1975.^{7/} Moreover, even with a partial rebuilding of inventories, prices remained at their February 1975 level through June 1976. Some softening of prices is likely as stocks are rebuilt. In addition, 1976 annual sales or use of rock were forecast to be 3 percent lower than the 46.6 million tons in 1974.^{8/}

The price of wet-process phosphoric acid has generally been responsive to changes in demand, even though the industry is relatively concentrated. So has capacity. It increased briskly both early in the sixties and in the seventies (table 21) in response to large demand. After the large buildup of capacity between 1960 and 1967, prices began to slow. By 1969 (similar to the situation in the anhydrous ammonia industry), excess capacity had been built, leading to large inventories of acid, further softening of prices, closing of small plants, and operating of large plants at below-capacity rates. By 1971 and 1972, demand had reduced inventories, causing plants to increase their operating rates and the industry in general to expand its capacity. Prices nearly tripled between 1972 and 1975. There appears now, however, to be some softening, as 1976 industry capacity was about 2.1 million tons over its 1975 level.

There has been considerable variation as well in prices for concentrated superphosphate since 1960. In 1960, an estimated 1 million tons of product were produced, and farmers paid an average of \$81 per ton (table 22). By 1967, annual

^{7/} "Value" as developed by the Bureau of Mines is based on reports by the industry to that agency. The average figure shown reflects either actual sales or, if the rock is used captively by a given company, cost plus a reasonable profit.

^{8/} See (47, 57).

capacity increased to 2.32 million tons, but production was only 1.78 million. Nonetheless, the price increased to \$84 by the end of that year. For the following 3 years, capacity utilization was relatively low, and prices declined to a low of \$74 in 1969. Prices began to climb again in 1970, reaching a peak of \$214 per ton in 1975.

Structure and Organization

In examining the structure of the phosphate fertilizer industry, it is informative to utilize several orientations: for phosphate rock, the geographical distribution of rock reserves, production, and consumption; and for phosphate rock and other phosphatic products, the concentration of ownership and vertical integration characteristics among those subsectors. Some of the subsequent discussion, especially that relating to phosphate rock, is presented with both world and domestic orientations. But concentration and vertical integration characteristics are discussed with regard to only the domestic industry.

Phosphate Rock

Several investigators have made estimates of world phosphate rock reserves.^{9/} Over time, total reserve estimates have increased as new phosphate deposits have been discovered. Metallurgical developments have increased P2O5 recovery from former plant wastes and permitted utilization of lower grade ores. And, information on existing deposits has improved. The greatest concentrations of total reserves are in the United States, the Soviet Union, and Morocco (table 23). It is likely that as reserves are increasingly exploited in those areas, more deposits in North Africa and Australia will be utilized.

Phosphorous-bearing rock deposits of commercial grade are found domestically in several States, 7 of which had 1976 combined reserves of 4.9 billion tons of P2O5 (table 24). In table 24, "Other Resources" include unknown mineral deposits (whether recoverable or of subeconomic grade) that are geologically predictable as existing in certain areas.

Location of production.--Worldwide production of phosphate rock in 1974 was 122 million short tons. The United States produced 38 percent, or nearly 46 million tons. Other major producers were the Soviet Union (20 percent), Morocco (18 percent), and Tunisia (4 percent) (table 25). Neither the United States nor the Soviet Union was able to meet their respective combined domestic and export demands for rock in 1973 and 1974. Morocco filled these gaps, in some instances at prices well above those prior to 1973.

The location of global phosphate rock production differs considerably from that of potential reserves. On the one hand, the United States and the Soviet Union in 1974 accounted for only 8 and 5 percent of the resources, respectively, but they supplied 38 and 20 percent of the world production. On the other hand, Morocco, with 72 percent of the world's estimated resources, produced only 18 percent of the total world supply. This production disparity is partly the result of demand areas. The United States and the Soviet Union are the largest consumers of P2O5, accounting for 28 and 15 percent of the total global disappearance (table 25). Morocco, on the other hand, consumes less than 1 percent of the world total.

^{9/} See, for example (14, 47).

The principal exporting areas are the United States, Russia, North Africa, and the Pacific Islands of Nauru, Christmas, and Ocean. The major recipients of the rock are Western Europe, Eastern Europe, Japan, Canada, and South America (47).

Domestically, there are three major rock-producing areas: Florida and North Carolina, the Western States, and Tennessee. Of these three, Florida and North Carolina produce the greatest quantity of rock, over 80 percent of total U.S. marketable production each year since 1968 (table 26). In 1975, total production was 49 million tons of which Florida and North Carolina contributed 83 percent. It is likely in the future that the Western States will provide a greater share of the total. The reserves of that area far exceed actual production, and the quality of Florida rock reserves is likely to continue to decline.

Concentration and diversification.--Concentration in the phosphate rock sector has generally declined since 1900, although there have been significant variations in the degree of control in the industry. Prior to 1900, there were numerous rock-mining firms in the United States--over 100 in 1892. By 1913, only 11 pebble-rock producers were supplying the domestic market (23). Nearly all were large commercial fertilizer producers. The five largest produced 73 percent of the rock consumed in the United States in 1913.

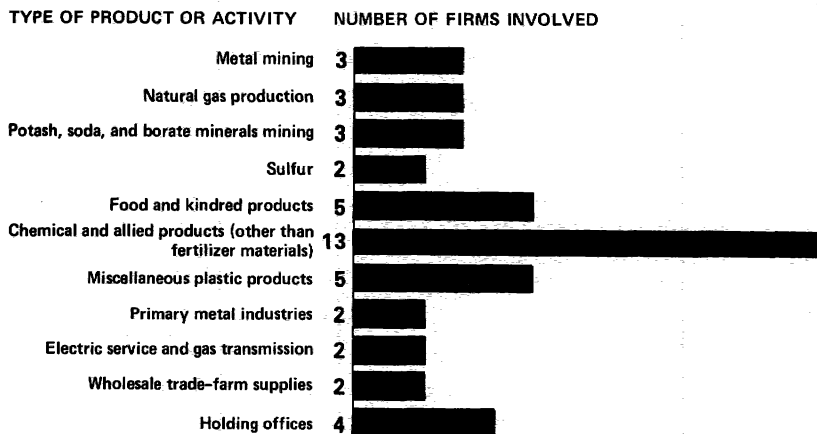
In 1952, there were 30 domestic rock producers. Thirteen were in Florida, and 7 of the 13 produced 74 percent of the rock sold or used domestically. By 1967, the number of domestic producers declined to 19, but capacity was almost 42 million tons (app. table 8). The top 4 firms in 1967 controlled 49 percent of total capacity, and the top 10 controlled 84 percent. By 1970, capacity increased to 51 million tons with the addition of 2 firms to the industry. Both the 4- and 10-firm concentration ratios fell, to 48 and 83 percent, respectively. At present, there are 22 firms operating 29 mines with a combined annual capacity of 61 million tons of rock. Average annual capacity per firm is 2.8 million tons, compared with 2.1 million tons in 1967. The top 4 and top 10 concentration ratios are 50 and 81 percent. The 6.3-million-ton increase in capacity of the top four firms between 1970 and 1976 was a result of plant expansions by three firms which offset a mine shutdown by the other firm.

There has been, over time, an increasing tendency toward vertical integration among the product subsectors making up the phosphate fertilizer industry. Producers of phosphate rock are involved extensively in the production of wet-process phosphoric acid, concentrated superphosphate, and ammonium phosphate. At present, 11 firms produce both phosphoric acid and phosphate rock, 10 produce rock and concentrated superphosphate, and 13 produce rock and ammonium phosphate (table 27). The 11 firms in both rock and acid production control 74 and 49 percent of the respective capacities of those two sectors. Similar figures for the 10 rock and concentrated superphosphate producers are 69 and 62 percent, and for all the 13 rock and ammonium phosphate producers, 89 and 61 percent.

The importance of sulfuric acid to the phosphate industry is illustrated in table 27. Fourteen firms produce both rock and sulfuric acid and own 89 and 42 percent of the total industry capacity for those two products. Further, 23 firms produce both sulfuric and wet-process phosphoric acids and own 73 and 85 percent of the respective total productive capacities for those products.

Phosphate rock producers are involved not only in other parts of the phosphate sector but also in less-related industries (fig. 10). In 1975, 13 rock producers were engaged in the allied chemicals industry (chemicals other than fertilizers), 5 were involved in food and kindred products, and 5 were involved in miscellaneous

INVOLVEMENT OF PHOSPHATE ROCK PRODUCERS AND THEIR PARENT FIRMS IN THE PRODUCTION AND DISTRIBUTION OF OTHER PRODUCTS, 1975



USDA

NEG. ERS 2672-77 (1)

Figure 10

plastic products. Three were in the metal mining industries. Generally, rock producers' involvement in other product lines is confined to the production of closely allied goods and services.

Phosphoric Acid

Location of production.--The major domestic areas for phosphoric acid production correspond closely to the production areas for phosphate rock and sulfuric acid, the major inputs into phosphoric acid. Over 70 percent of the phosphoric acid manufactured in 1974/75 was produced in the three primary phosphate rock producing areas.^{10/} Nearly all acid producers purchase sulfur in Louisiana and Texas and produce sulfuric acid. They then use that product to manufacture phosphoric acid. Many phosphoric acid producers also make anhydrous ammonia which, along with phosphoric acid, is the major input into ammonium phosphates.

Concentration.--Between 1967 and 1976, the number of domestic firms producing phosphoric acid declined from 31 to 26 (app. table 9). At the same time, the capacity of the industry rose from 5.5 to 9.1 million tons of P2O5, and the share of the top 10 firms grew from 60 to 75 percent. The 4-firm concentration ratio increased from 31 percent in 1967 to 42 percent in 1971, then declined to 38 percent in 1976.

^{10/} The Appalachian, Southeast, and Mountain regions.

Much of the expansion in production capacity has been through the building of additional facilities by firms which were in the industry in 1967. At that time, seven firms had two plants each, and one firm operated three plants. By 1971, two of the seven firms had each added a third plant, several other plants had been expanded, and facilities built by firms new to the industry had added 940,000 tons of P2O5 to annual industry capacity. By 1976, three of the top four firms had expanded their plants and the fourth had added a new facility, adding 3.4 million tons of P2O5 to the industry's capacity. Nonetheless, capacity additions by other firms and new entrants into the industry lowered the share of the largest four firms from 42 to 38 percent.

Concentrated Superphosphate

Location of production.--As consumption of concentrated superphosphate has increased relative to normal superphosphate, there has been a tendency for producing plants to be more closely located to raw material sources than to markets. Concentrated superphosphate generally is made at a lower delivered cost when located near phosphate rock deposits than when located near consumption areas. As a consequence, over 75 percent of the 1976 U.S. concentrated superphosphate capacity was in the Southeast, the major phosphate rock area (table 28). These three rock-producing areas account for 93 percent of the capacity.

Concentration.--There has been virtually no shortage of capacity to produce concentrated superphosphate since 1966. At that time, 18 firms had productive facilities with a combined annual capacity of 2.1 million tons of P2O5 (49). The top 4- and top 10-firm concentration ratios were 50 and 86 percent, respectively. By 1972, several firms had exited the industry and left a total firm count of 12, a capacity of 1.8 million tons of P2O5, and higher 4- and 10-firm concentration ratios of 63 and 96 percent. Between 1972 and the end of 1975, capacity expanded to 2.7 million tons of P2O5, as new firms entered the industry or as previous producers re-entered at other locations. The shares of the top 4 and top 10 firms declined to 60 and 89 percent (51).

Ammonium Phosphates

Location of production.--Nearly 70 percent of the 1976 U.S. production capacity for ammonium phosphates is located in the Southeast and Delta States, the areas of greatest relative availability of the two primary inputs, phosphoric acid and anhydrous ammonia (table 29). Conversely, the major areas of consumption are the Corn Belt, Northern Plains, and Lake States. The primary reason that production is more input- than market-oriented is that transportation rates favor the shipment of finished product rather than either or both of the inputs.

Concentration.--Trends in capacity and concentration of ammonium phosphate facilities have been similar to those for other phosphate fertilizer materials. In 1964, there were 29 firms producing ammonium phosphates with a combined capacity of 1.2 million tons of P2O5 (49). The top 4 and top 10 firms controlled 49 and 85 percent of industry capacity, respectively. By 1971, capacity had grown to 3.1 million tons of P2O5 and was controlled by 40 firms. Concentration at both the 4- and 10-firm levels declined considerably from 1964 to 41 and 70 percent. Capacity in 1976 was 4.9 million tons of P2O5 (51). There were 30 firms producing ammonium phosphates at 42 locations, and the 4- and 10-firm concentration ratios rose slightly from 1971 to 47 and 72 percent.

POTASH FERTILIZER SECTOR

Potash production in the United States increased from 1960 to 1966 and has declined since then. From 1966 to 1969, the potassium chloride component of total domestic potash production decreased and then stabilized at about 78 percent. The remaining domestic production is composed of potassium sulfate, manure salts, soluble and chemical muriates, and potassium-magnesium sulfate.

The percentage of fertilizer consumption satisfied by all imports has been increasing to a current level of 77.1 percent (35). Further, the percentage of fertilizer consumption satisfied by imports from Canada has been increasing (currently 74.8 percent) as has Canadian production. The increasing reliance on potash imports from Canada is because of the higher ore grades in Canada, lower transportation costs to the Midwest, and lower production costs. The U.S. net trade balance (imports less exports) has been increasing, as imports have increased and U.S. production has decreased (fig. 11). In 1974/75, total domestic consumption was 4.5 million tons of K2O, imports from Canada were 3.7 million tons, and U.S. exports were 0.6 million tons.

Potash fertilizer demand has been increasing (fig. 12). This is consistent with the increases in nitrogen and phosphate demand and is generated by the nutrient balance needed by plants. The percentage of total potash demand for fertilizer use has remained relatively constant at about 95 percent.

Prices

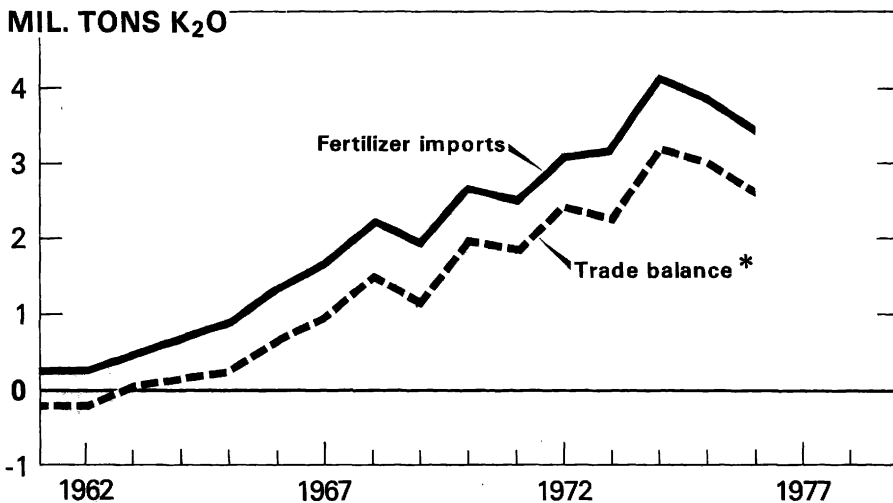
U.S. potash prices have been greatly influenced by foreign sources of supply. European cartels generally controlled potash prices and sales in the United States until 1939. A German cartel, formed in 1879, was the major U.S. supplier of potash prior to their World War I embargo on German potash exports. The cartel had virtual monopoly control over international trade in potash. Under the German Potash Law of 1910, the German Potash Syndicate obtained complete monopoly control over potash production in Germany. Nonetheless, potash prices in the United States were comparatively stable from 1897 to 1915 at \$34-\$39 per ton (\$.57-\$.65 per 20-pound unit of K2O).

At the end of World War I, France acquired the rich Alsatian potash deposits. The French quickly entered into competition with the German cartel in international potash markets. The resumption of imports and this competition drove U.S. potash prices down to \$0.63 per 20-pound unit of K2O by 1923 (table 30). German producers initiated negotiations with France shortly after the French started exporting potash in 1919. The result of the agreement, reached in 1924, was that Germany and France formed the Potash Importing Company (incorporated in New York) to act as the exclusive sales agent for the two parties. Potash prices were again brought under control of a single organization, and, with the exception of an outbreak of competition initiated by the Soviet and Spanish producers in 1934 and 1935, prices were largely under its control until World War II.

In 1935, Spain was invited to join the cartel, and the USSR accepted its price leadership, resulting in the return of price and supply control to the cartel. Prices again gradually moved upward from \$0.42 per 20-pound unit of K2O in 1935 to \$0.52 in 1940 and remained at that level through 1949.

U.S. TRADE IN POTASH

Selected Data



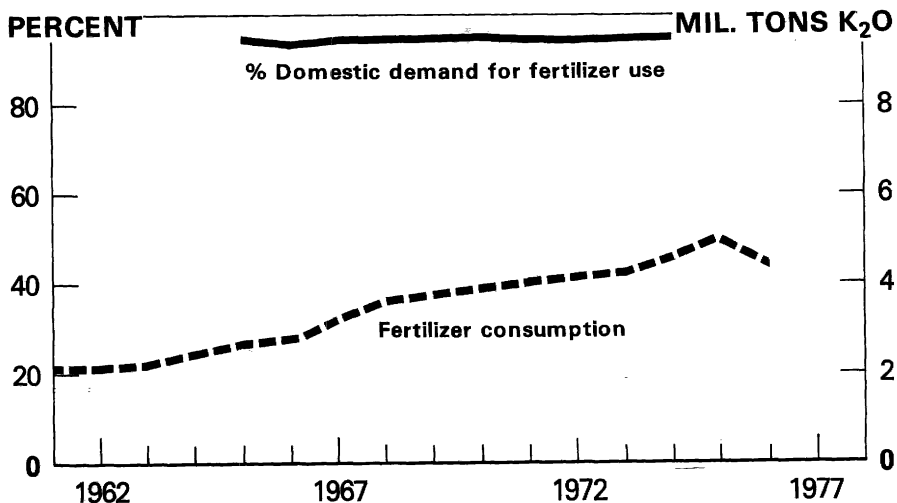
*IMPORTS MINUS EXPORTS.

USDA

NEG. ERS 2678-77 (1)

Figure 11

DOMESTIC FERTILIZER DEMAND FOR POTASH



USDA

NEG. ERS 2676-77 (1)

Figure 12

The Potash Importing Company controlled almost all potash sales in the United States, and its operation became a violation of the Sherman Act. The U.S. Department of Justice on April 7, 1927, filed a petition in equity, charging the Potash Importing Company with conspiring to restrain trade in the sale of potash in the United States.^{11/} The result of the suit was that the parties consented to a decree. The terms simply required the defendants to incorporate their joint selling agency in some other country. Nonetheless, they were allowed to have a branch office in New York to sell potash. Therefore, they still retained control of potash prices.

Just before World War II, the United States became self sufficient in potash. By 1941, exports exceeded imports. Price controls were lifted early in the fifties after the dissolution of Office of Price Stabilization. Prices were comparatively steady until 1968 and 1969, when the huge Canadian production potential was realized, and North American production capacity increased sharply (table 31).

The Canadian producers' costs were lower than other producing countries because of the latter's older plants and poorer grades of material. The Canadians' lower cost and increased production set off some effective competition in the global potash markets, resulting in lower prices for U.S. farmers--in 1968, prices were approximately 19 percent below those of 1967. Canadian producers undercut the prevailing prices to gain a share of the market commensurate with their share of the global production capacity.

From the low of \$45 paid by farmers per ton of 60-percent muriate in 1968, potash prices increased to \$54 per ton in September 1970. This increase of 20 percent resulted from the establishment of (1) a minimum price equivalent to \$18.75 (U.S.) per ton of 60-percent K20 standard grade potash, f.o.b. mines, by the Saskatchewan Potash Conservation Board and (2) output limitations of approximately 45 percent of production capacity. Prices were stable in 1971 and 1972 until demand outstripped production capacity. Prices increased in the following 3 years to about 200 percent of the 1970 level, but they declined in 1976.

Future prices and quantities of Canadian potash are somewhat uncertain because of the dispute between potash producers and the Saskatchewan government. The primary issue is the size of the economic rent the government feels that both U.S. and Canadian firms should pay for mining the potash resource in Saskatchewan. The Saskatchewan government claims that its objectives are to obtain a fair share of the province's potash resources and to have some control over future expansion of the industry's productive capacity (4). The government proposed a tax structure that it felt would accomplish its objectives, but the industry countered that the system was unjust and that they would not cooperate. The provincial government countered by establishing the Potash Corporation of Saskatchewan, a separate corporation of the Crown, to acquire potash interests in the province. Thus far, the Corporation has purchased one mine and will likely purchase others as well. The government's announced objective is to acquire at least 50 percent of the potash productive capacity in Saskatchewan (4).

Members of the U.S. fertilizer industry are not certain what impacts the Saskatchewan government's actions may have. Although the Potash Corporation of Saskatchewan claims that it intends to be aggressive in seeking new customers and to be competitive with regard to price and quantity, there is some apprehension that future production may be reduced and floor prices set, as they were in 1969 and 1970.

^{11/} U.S. vs. Deustches Kalisyndikat Gesellschaft, Equity No. 41-125, Southern District of New York. April 7, 1927.

Other complications have been added by recent U.S. Federal indictments of several major domestic producers, charging that the companies conspired to restrict production and stabilize prices at uncompetitive and artificial levels, a violation of the Sherman Act.

Structure and Organization

The domestic potash industry developed because of the cessation of imports and increasing prices during World War I. By 1918, the industry consisted of 128 producers, 51 that produced potash from wood ashes and 77 that produced from other sources, primarily brine from Searles Lake and the Great Salt Lake area (23). However, only one of these producers survived the precipitous price declines that followed the resumption of imports from France and Germany after World War I.

Upon the discovery of potash deposits near Carlsbad, New Mexico, in 1925, the United States became more self sufficient in the nutrient. By 1941, when the United States became a net exporter of K2O, three companies, sole producers in New Mexico fields, accounted for 95 percent of total domestic production.

In 1960, industry concentration was still high, with eight firms operating all of the U.S. mining and beneficiation facilities. Combined capacity was 2.5 million tons of K2O (fig. 13), and the top four producers operated 71 percent of the domestic capacity.

The discovery and development of rich potash deposits in Saskatchewan, Canada, by six of the eight U.S. potash producers in the latter part of the sixties started the shift to Canada for the U.S. source of potash. By 1967, three U.S. firms were operating facilities with 2.1 million tons of production capacity in Canada (app. table 10). The 11 U.S. firms producing domestically had 4.0 million tons of production capacity. In total, U.S. firms operated mines with production capacity of 6.0 million tons in the United States and Canada. The top four firms operated 65 percent of the combined capacity, a reduction from 1960. Two of these four firms operated 45 percent of the U.S. and Canadian production capacity. By 1967, Canada was supplying over 88 percent of U.S. imports of potassium chloride and 53 percent of total U.S. domestic consumption.

By 1971, Canadian mines supplied 98 percent of U.S. potash imports and 70 percent of the K2O consumed. In 1971, 15 firms in the United States and Canada operated mines and beneficiation plants with a capacity of 10.8 million tons of K2O and produced 6.6 million tons. The top four firms, operating in both the United States and Canada, controlled 56 percent of the production capacity of the two countries, a decline from 1967. Concentration of production capacity controlled by the top 10 firms also declined from 99 percent in 1967 to 90 percent in 1971.

In 1976, 15 potash firms operated in the United States and Canada with a capacity of 10.6 million tons of K2O. Their concentration has not changed significantly. The top five firms retain the same position that they held in 1971. These firms continue to increase production enough to satisfy only the increasing demand at or above the minimum price level of \$18.75 per ton of potassium chloride set by Saskatchewan. Further, they still have unused capacity; 8.5 million tons were produced in 1975 in facilities with capacity of 10.6 million tons.

Known global reserves are ample for the foreseeable future, well beyond the end of this century or the next. Nearly half of the estimated 11 billion tons of K2O reserves are in North America (table 32). Domestic potash reserves, estimated at 0.2

PRODUCTION CAPACITY AND CONCENTRATION RATIOS IN THE U.S. POTASH INDUSTRY

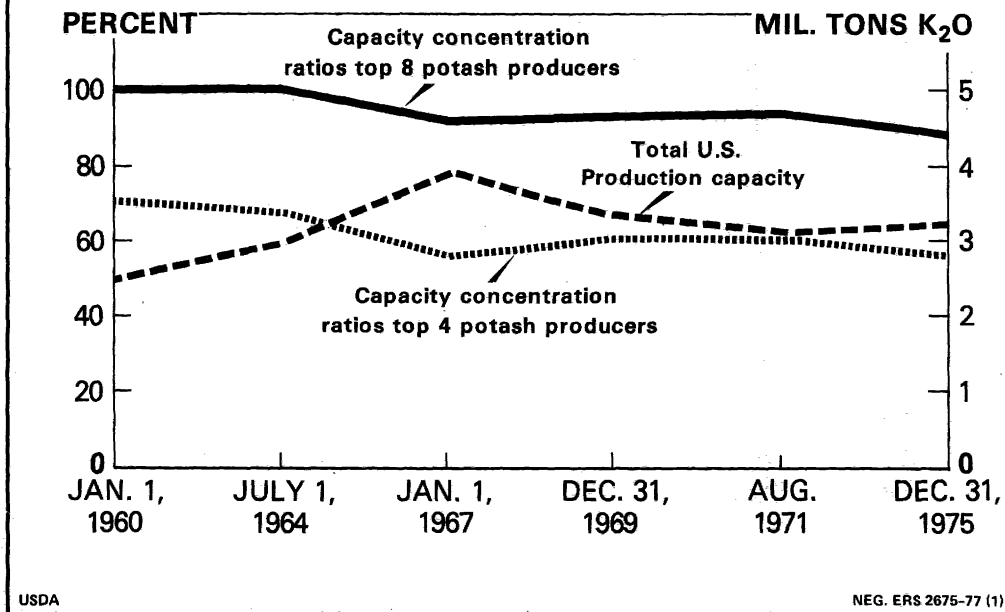


Figure 13

billion tons of K₂O, are less than 2 percent of the estimated world reserves. Deposits of 100 million tons are bedded in New Mexico.

Global potash resources include another 76 billion tons of K₂O, and about 91 percent of these are in North America (United States, 0.3 percent, and Canada, 91 percent). Other sizable resources are in East Germany, West Germany, Russia, Israel, and Jordan.

The Canadian reserves of 5 billion tons of K₂O account for 45 percent of the global reserves. This does not include deposits in New Brunswick Province where potash has been found, but the extent of which is not certain. However, they are not likely to be of the same magnitude as the Saskatchewan reserves. Nonetheless, New Brunswick's reserves, within 50 miles of Fundy Bay, have a significant transportation cost advantage over Saskatchewan producers, especially in the export market and to the East and Southeast U.S. markets.

Potash production is naturally tied to the locations of potash deposits. Producers mine and beneficiate the matrix at or near the mine site and ship most of the product directly to the retailer to minimize the cost.

The reserves from which the United States draws its supply are in California, Utah, New Mexico, and Canada. Production capacities at these reserves are 0.2, 0.4, 2.4, and 8.3 million tons of K₂O, respectively (31, 51).

Potash producers engage in the production and distribution of a variety of goods and services. However, the conglomerate nature of the potash mining industry is not

so significant as that of the anhydrous ammonia or the phosphate rock mining industries. Figure 14 shows a significant involvement on the part of the potash industry in the production of chemicals and allied products, with 9 firms falling into this category. The heaviest involvement, however, appears to be in areas of mineral mining and primary metals. As in the case of phosphate rock producers, potash producers' involvement in other areas is confined to the production and distribution of goods and services closely related to potash.

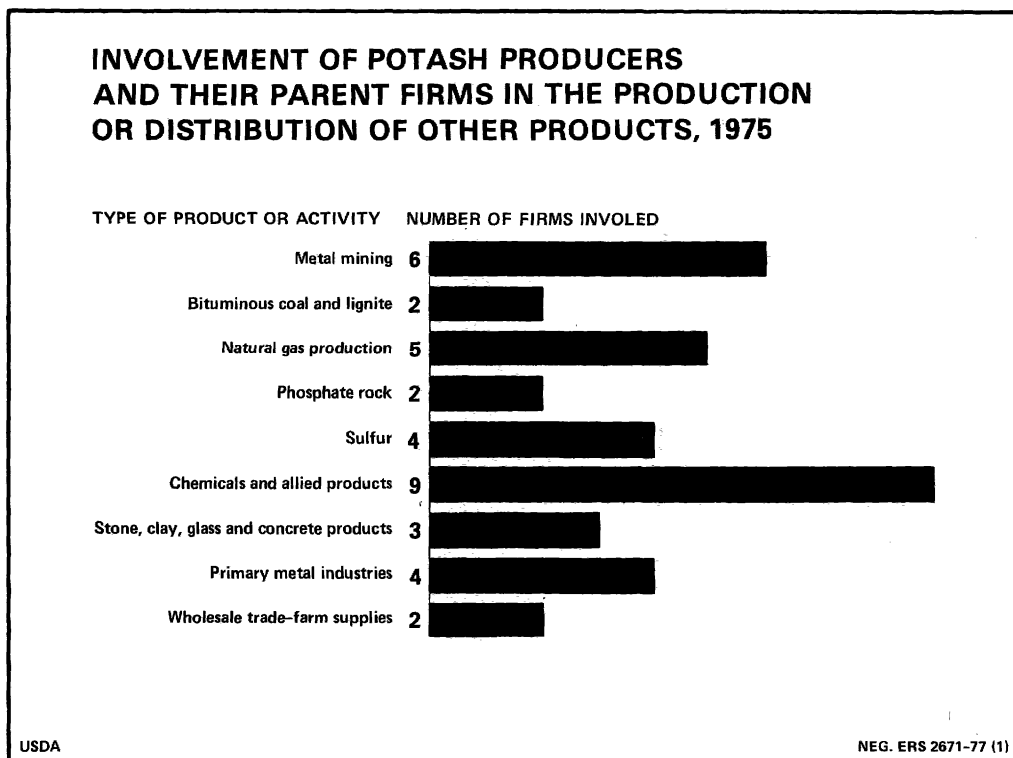


Figure 14

STORAGE AND TRANSPORTATION

Fertilizers are of little value to farmers or others unless the products are available when and where they are needed. The relative concentration of fertilizer production facilities in a few areas of the United States and the scattered seasonal use of the products make critical the movement to and storage of fertilizers at the points where they are used. With the trend toward larger production facilities, the development of adequate onsite and offsite storage and transportation facilities is even more essential.

In general terms, fertilizer storage is essential because of the differences in temporal and spatial patterns of fertilizer production and use. The demand for fertilizer is highly seasonal, with the annual peak corresponding directly to planting in the spring. Because of economic and engineering factors, fertilizer production must continue throughout the year. The continuing trend toward larger production facilities and economic, engineering, and other reasons further complicate the problem. Product storage, which may be at the point of production, consumption, or at some intermediate location, offers the capability to match year-round production with seasonal consumption.

A major trend since early in the sixties has been a buildup in storage capacity in market areas, where the materials are used, and away from production sites. Two major reasons for this change are large product volumes sold in the spring planting season and greater emphasis on efficient use of transportation equipment. By shipping and storing materials on a year-round basis, producers can avoid large inventories and bottlenecks at the production site. Stocks may become significant bottlenecks in the peak season, and demand may easily outstrip the producer's ability to load and move products. By shipping to offsite storage facilities, producers may smooth out the entire production and marketing process.

Types of Storage Facilities

Different types of storage facilities are required for gaseous products (anhydrous ammonia), dry bulk and dry bagged products, nonpressure and pressure liquids, and fluid acids. Ammonia (a gas at normal temperature and pressure) is handled and stored in liquid form by pressurization or refrigeration of the gas. Large onsite and terminal facilities as well as barges store ammonia under refrigeration. In smaller quantities (for example, at retail dealers and other distributing outlets), the compound is held in high pressure tanks with the temperature uncontrolled. These vessels are commonly spherical, fabricated of iron or steel, and, among onsite locations in the United States, have capacities ranging from 100 to 3,000 tons of ammonia (8).

Refrigerated storage is in tanks under medium or atmospheric pressure. The former are usually spherical, and both types are covered with insulation to reduce heat input. A refrigeration unit is connected to the vessel, and the contained ammonia is used as the refrigerant. Because some of the liquid vaporizes after absorbing heat, the tank pressure is maintained by drawing off vapors. This vapor is compressed, condensed, and returned to the vessel as a liquid (28).

Refrigerated storage at atmospheric pressure is among the newer developments in fertilizer storage technology and is by far the most practical method for containing

large quantities of ammonia. It involves refrigerating the product to or below its boiling point of 28 degrees below zero F, at which point ammonia remains a liquid at atmospheric pressure. The vessels may be of one or two walls, with the latter type having insulation between the walls. The capacities of refrigerated storage vessels among U.S. ammonia producers range from 750 to 40,000 tons, with 30,000 tons a common size for many terminal locations (8).

Storage facilities for dry solid products and solutions are less complex than those for ammonia. Dry materials are usually stored in compartmentalized buildings resembling warehouses. Humidity controls are built into the facilities for those products which cake easily. Nonpressure solutions are usually stored in mild steel tanks serviced by pumping equipment. Pressure solutions are often stored in stainless steel vessels.

Transportation

Transportation costs represent a significant component of the final delivered price a farmer pays for the fertilizer. The place utility provided by transportation has become an increasingly important component of fertilizer marketing decisions as producers seek methods to meet seasonal demands in the industry. The impacts on structural characteristics have been manifold, including the proliferation of small market area bulk-blending facilities, more trade among producers to lessen the impact of transportation costs, and so forth.

The four major modes of transporting fertilizer materials are barge, railroad, truck, and pipeline. Barge traffic has become a major medium for moving anhydrous ammonia and other products from Gulf Coast production sites to the Corn Belt on the Mississippi, Illinois, Ohio, and Missouri Rivers (20). The units used to carry anhydrous ammonia have independent cylindrical tanks mounted in a hopper-design vessel and are free to expand or contract independent of the hull structure (making them preferable as well for cargoes such as molten sulfur at 280 degrees F). Ammonia is commonly transported in barges having total capacities of 1,000 to 3,000 tons. Storage may be under high pressure (250 psi) or refrigeration. In the latter type units, onboard refrigeration facilities must be adequate to maintain ammonia in its liquid phase.

The main watergoing vessel used for transporting dry fertilizer products is the covered barge. Usually constructed of welded steel, these vessels have covers of different designs to protect the product shipped from the elements. Popular barge sizes are 1,000 and 1,500 tons. The shallow channels of certain waterways necessitate the movement of partly loaded barges, thus increasing the average transport cost. Nonetheless, the large market area adjacent to the Mississippi River Valley favors the continued use of barge transport.

Railroad tank cars utilized to transport ammonia have a liquid capacity of 25 to 70 tons. The 25-ton standard units are comprised of two tanks with a layer of insulating material between them. The inner tank is a high pressure vessel (300 psi), and the outer covering is a light steel shell. The larger cars (70 tons) have noninsulated tanks with a pressure capacity of 400 psi (28).

Trucks used to ship anhydrous ammonia are often semitractor trailer units carrying high pressure tanks (262 psi) with liquid capacities of 12 to 19 tons. Trucks, barges, and railroad tank cars are often used to ship liquid propane gas in the ammonia off-season. Covered trailers may be used for dry products, either bulk or bagged (28). Unpressurized and low-pressure tank trailers are utilized to

transport nonpressure and low-pressure nitrogen solutions. Trucks are usually favored for their relative speed and flexibility in moving products from terminal storage locations to dealers or distributors.

Pipelines represent the most recent transportation development in fertilizer marketing. Used primarily for anhydrous ammonia but also for some nonpressure nitrogen solutions (27), pipelines were first announced in 1968, and several have been built since then. They link the Gulf Coast area (site of the greatest concentration of ammonia production) with heavy use areas, especially the Corn Belt. They are designed primarily to serve a market area located away from the navigable Mississippi River and other rivers. In such market areas, pipelines compete effectively with systems of barges and river terminals. The identity of individual lots is lost in the pipelines, and shipment (which accordingly can be made with zero delivery time) is from a common "stream."

There were significant changes in transportation modes used by fertilizer producers between 1967 and 1972, the last 2 years for which comparable data are available. Data in table 33 show a shift toward greater utilization of motor carriers, private trucks, and water transportation and less use of rail facilities. The shift is most dramatic for anhydrous ammonia. The percentage shipped by rail declined from 71 percent to 40 percent; by all trucks (motor carriers and private vehicles), increased from 6 percent to 29 percent; and by water, increased from 23 to 32 percent. It is likely that the trends indicated will continue, as further uncertainty regarding rail-line abandonments and car availability has caused many manufacturers to purchase their own trucks. Future data will indicate the growing importance of pipelines.

CONCLUSIONS

Price responses indicate that competitive supply and demand forces are working in the fertilizer manufacturing industry, more so in the nitrogen and phosphate sectors than in potash because of cartels and Government controls in potash. However, the speed of the industry's adjustment to changes in domestic and worldwide demand has slowed over time because of uncertainties in a number of areas. The consequences have been a perennial mismatching of supply and demand, erratic prices and profits due in part to price and other controls on the industry, and increasing concentration and vertical and horizontal integration. Further, barriers to entering the industry have increased because of greater capital costs and uncertain prices and availabilities of resources and raw materials.

Prices for nitrogen and phosphate products declined between 1961 and 1969, as new productive capacity more than met growing demand. Prices stabilized through 1972, as no additional capacity was added. Then, prices began increasing dramatically in 1973, as demand rose in response to famines and other phenomena. Consumption rose to a record 47.1 million tons of all fertilizer in the 1973/74 fertilizer year, and to 48.9 million tons in 1975/76. Prices peaked early in 1975, then declined, as farmers responded predictably to high prices with reduced purchases at the same time that new capacity was being added. Fertilizer prices started declining, and with a weakening of some crop markets, fertilizer use and prices continued to slip. October 1976 prices were about 23 percent lower than the April 1975 peak. Consumption in the year ending June 30, 1976, was an estimated 48.9 million tons.

Fertilizer producers face serious uncertainties on the cost and revenue sides of the industry. Construction costs for many types of fertilizer facilities have skyrocketed since 1970. Further, producers are uncertain of the future availability and cost of natural gas and, consequently, of the feedstock cost for manufacturing anhydrous ammonia. There have been no announcements of new ammonia plants opening beyond 1978, as the feasibility of these large investments can change quickly.

The fertilizer industry faces other uncertainties which make investments in new facilities even more risky. The Government's energy programs have a direct impact on the price and availability of natural gas and other fuels and, consequently, on the production costs of fertilizers. Pollution abatement costs may reduce or eliminate the profitability of existing or planned facilities. The primary sources for other raw materials, such as potash, may be curtailed, forcing what may be a costly search for alternative supplies. Finally, farmers' planting intentions, fertilizer application rates, and the weather are all highly uncertain and of importance to fertilizer producers.

Uncertainties, economies of scale, and the capital-intensive and technical orientation of fertilizer manufacturing plants have made it more difficult and costly to enter the industry. Firms with production facilities that were operating early in the seventies are at a considerable competitive advantage relative to new firms, because of the sharply escalated capital costs in the last 6 years. Future supplies and prices of fertilizers depend importantly on how fertilizer producers' investment plans are affected by their perceptions of uncertainties on both the supply and demand sides of the market.

Table 1--Total and primary nutrient consumption of all
fertilizers in the United States ^{1/}

Year ending on June 30	Total consumption (Product)	Consumption of primary nutrients			
		Nitrogen (N)	Phosphates (P2O5)	Potash (K2O)	Total
		1,000 tons			
1950.....	18,343	1,005.4	1,949.8	1,103.1	4,058.3
1955.....	22,726	1,960.5	2,283.7	1,874.9	6,119.1
1960.....	24,877	2,738.0	2,572.4	2,153.3	7,463.7
1961.....	25,567	3,030.8	2,645.1	2,168.5	7,844.4
1962.....	26,615	3,370.0	2,807.0	2,270.5	8,447.5
1963.....	28,844	3,929.1	3,072.9	2,503.4	9,505.4
1964.....	30,681	4,352.8	3,377.8	2,729.7	10,460.3
1965.....	31,836	4,638.5	3,512.2	2,834.5	10,985.2
1966.....	34,532	5,326.3	3,897.1	3,221.2	12,444.6
1967.....	37,081	6,027.1	4,304.7	3,641.8	13,973.6
1968.....	38,743	6,787.6	4,453.3	3,792.6	15,033.5
1969.....	38,949	6,957.6	4,665.6	3,891.6	15,514.8
1970.....	39,589	7,459.0	4,573.8	4,035.5	16,068.3
1971.....	41,118	8,133.6	4,803.4	4,231.4	17,168.4
1972.....	41,206	8,022.3	4,873.7	4,326.8	17,212.8
1973.....	43,288	8,295.1	5,085.2	4,648.7	18,029.0
1974.....	47,094	9,157.2	5,098.6	5,028.6	19,338.4
1975.....	42,508	8,607.7	4,511.0	4,452.6	17,571.4
1976 ^{2/} ..	48,864	10,344.9	5,215.2	5,207.6	20,767.7

^{1/} Includes Puerto Rico.

^{2/} Preliminary.

Compiled from (61).

Table 2--Consumption of primary plant nutrients by crop production region as a percentage of total U.S. consumption

Region	Nitrogen (N)		Phosphate (P2O5)		Potash (K2O)		Total	
	1950	1975	1950	1975	1950	1975	1950	1975
	Percent							
Northeast.....	9	4	15	6	15	6	13	5
Lake States.....	3	8	8	11	10	16	7	11
Corn Belt.....	10	28	19	33	20	40	18	32
Northern Plains..	2	15	2	10	2	3	2	11
Appalachian.....	17	6	20	9	20	11	19	8
Southeast.....	21	8	18	8	21	13	19	9
Delta States.....	15	5	5	4	5	4	8	5
Southern Plains..	3	9	5	7	2	3	4	7
Mountain.....	2	5	2	5	2	1	2	4
Pacific.....	12	10	4	6	2	2	5	7
Other.....	6	2	2	1	1	1	3	1

1/ Includes Alaska, Hawaii, Puerto Rico.

Source (61).

Table 3--Anhydrous ammonia, phosphate rock, and potash: Structural data, U.S. firms, January 1, 1976

Fertilizer material (basis)	Number of firms	Number of plants	Total annual production capacity 1,000 tons
Anhydrous ammonia (material)...	57	92	17,807
Phosphate rock (P2O5).....	21	28	61,100
Potash (K2O).....	11	11	2,976

Table 4--Involvement of anhydrous ammonia producers in phosphate and potash production, December 31, 1975

Fertilizer material (basis)	:	:	:	:
	:	Ammonia	Aggregate	Aggregate ca-
	:	firms	capacity	capacity owned :
	:	engaged in	owned by	by ammonia :
	:	production	ammonia firms	firms as a :
	:	:	:	percentage of :
	:	:	:	U.S. capacity:
	:	<u>Number</u>	<u>1,000 tons</u>	<u>Percent</u> <u>1,000 tons</u>
Phosphate rock (rock).....	:	13	33,450	59 2,573
Wet process	:			
phosphoric acid (P205)...	:	18	5,508	67 306
Wet process	:			
superphosphoric acid	:			
(P205).....	:	3	289	43 96
Ammonium phosphates (P205) :	:	19	3,848	88 205
Nitric phosphate (P205) ...:	:	1	60	100 60
Normal	:			
superphosphate (P205) ...:	:	9	480	58 53
Concentrated	:			
superphosphate (P205) ...:	:	11	1,979	84 180
Potash (K20)	:	2	530	16 265

Source: (51).

Table 5--Involvement of phosphate rock producers in nitrogen and potash production, December 31, 1975

Fertilizer material (basis)	Phosphate rock firms engaged in production	Aggregate capacity owned by phosphate rock firms	Aggregate capacity owned by phosphate rock firms as a percentage of U.S. capacity	Average annual capacity of firm
	Number	1,000 tons	Percent	1,000 tons
Ammonia (material).....	13	4,894	26	376
Nitric acid (100% HNO ₃) (material).....	5	1,217	12	244
Ammonium nitrate (material).....	5	1,196	17	239
Ammonium sulfate, coke oven (material).....	1	126	16	126
Ammonium sulfate, prime (material).....	3	269	26	90
Urea (material).....	8	1,288	23	161
Nitrogen solutions (material).....	4	649	0	162
Potash (K ₂ O).....	2	560	17	280

Source: (51).

Table 6--Involvement of potash producers in phosphate and ammonia production, December 31, 1975

Fertilizer material (basis)	Potash firms engaged in production	Aggregate capacity owned by potash firms	Aggregate capacity owned by potash firms as a percentage of U.S. capacity	Average annual capacity of firm
	Number	1,000 tons	Percent	1,000 tons
Phosphate rock (rock)...	2	15,500	27.2	7,750
Wet process phosphoric acid (P205):	3	1,466	26.6	489
Wet process phosphoric acid (P205):	2	304	45.5	152
Ammonium phosphates (P205).....	2	254	5.8	127
Normal superphosphate (P205):	2	122	14.8	61
Concentrated superphosphate (P205):	2	290	12.5	145
Anhydrous ammonia NH3)...	2	617	3.3	309

Source: (51).

Table 7--Prices paid by U.S. farmers for selected nitrogen fertilizers

Year	Anhydrous ammonia	Ammonium nitrate	Ammonium phosphate		Ammonium sulfate	Nitrogen solutions	Urea
			11-48-0	18-46-0			
Dollars per ton							
1960.	141.00	81.60	NA	NA	57.90	NA	117.00
1961.	142.00	82.70	NA	NA	58.20	NA	114.00
1962.	134.00	81.90	NA	120.00	57.00	NA	109.00
1963.	128.00	81.10	NA	117.00	52.20	NA	107.00
1964.	126.00	79.70	NA	110.00	52.60	NA	106.00
1965.	122.00	78.70	NA	111.00	53.40	NA	104.00
1966.	119.00	76.50	NA	108.00	52.80	NA	101.00
1967.	113.00	74.20	105.00	113.00	54.20	NA	99.30
1968.	91.40	67.90	104.00	101.00	53.90	NA	91.80
1969.	75.60	61.70	97.50	94.00	52.50	53.60	83.90
1970.	75.00	60.00	93.70	94.00	52.40	53.90	82.90
1971.	79.30	63.30	93.50	96.00	51.70	56.20	81.90
1972.	80.00	64.70	101.00	97.00	52.10	55.30	81.40
1973.	87.60	71.40	109.00	109.00	55.20	58.30	90.30
1974.	183.00	139.00	183.00	181.00	110.00	111.00	183.00
1975.	265.00	186.00	265.00	263.00	148.00	153.00	244.00

NA = not available.

Source: (60).

Table 8--Ammonia production capacity by crop production region
as a percentage of total U.S. capacity

Crop production region	Jan. 1960	July 1964	Jan. 1967	Dec. 1969	Aug. 1971	Dec. 1975	Change from 1960 to 1975
	Percent						
Northeast.....	4.5	3.9	2.6	4.1	3.9	2.8	- 1.7
Lake States.....	2.8	2.4	1.3	.2	.2	.2	- 2.6
Corn Belt.....	15.4	19.1	16.1	13.2	13.6	12.0	- 3.4
Northern Plains..	7.1	7.7	8.3	6.9	6.9	6.2	- .9
Appalachian.....	17.1	13.0	10.1	7.0	8.3	7.8	- 9.3
Southeast.....	6.0	9.0	7.1	5.2	4.0	3.9	- 2.1
Delta States.....	20.2	16.5	29.1	31.4	30.5	30.3	+10.1
Southern Plains..	12.2	18.2	14.2	19.7	19.4	22.1	+ 9.9
Mountain.....	1.6	1.4	1.8	1.7	1.7	4.5	+ 2.9
Pacific.....	13.0	9.6	9.3	7.5	7.5	7.6	- 5.4
Other (Alaska)...	--	--	3.0	3.0	3.0	2.7	+ 2.7

Source: (49).

Table 9--Vertical integration characteristics of anhydrous ammonia firms

Item	1975	1976	1977
	<u>Percentage of total</u>		
Ammonia firms owning one or more derivative plants <u>1/</u> ...	76	71	61
U.S. ammonia capacity owned by these firms <u>2/</u>	91	81	79
U.S. total ammonia derivative capacity owned by these firms.....	92	89	88

1/ Including ammonium nitrate, ammonium phosphates, and urea.

2/ In terms of 100 percent nitrogen equivalents.

Sources: (49, 51).

Table 10--Anhydrous ammonia derivative capacity owned by anhydrous ammonia firms

Derivative	Percentage of capacity owned by anhydrous ammonia firms		
	1975	1969	1964
Ammonium nitrate.....	92	92	99
Urea.....	97	96	90
Ammonium phosphates.....	86	78	58
Nitrogen solutions.....	95	NA	NA
Ammonium sulfate, prime..	68	NA	NA
Nitric acid.....	83	NA	NA

NA = not available.

Sources: (49, 51).

Table 11--Investment and operating costs for three sizes of anhydrous ammonia plants

Item	INVESTMENT AND WORKING CAPITAL					
	400-ton-per day plant		600-ton-per day plant		1,000-ton-per day plant	
	Cost per ton		Cost per ton		Cost per ton	
	Million dollars	Dollars	Million dollars	Dollars	Million dollars	Dollars
Investment						
Battery limits.....	15.0	37,500	20.0	33,333	28.0	28,000
Off site facilities.....	4.5	11,250	6.0	10,000	8.4	8,400
Total plant investment.....	19.5	48,750	26.0	43,333	36.4	36,400
Working capital.....	2.1	5,250	2.6	4,333	4.0	4,000
Total investment and capital.....	21.6	54,000	28.6	47,666	40.4	40,400
	OPERATING COSTS					
	Input measures					
	Unit/ Cost	Units per ton: Cost per ton	Units per ton: Cost per ton	Units per ton: Cost per ton	Units per ton: Cost per ton	Units per ton: Cost per ton
	Unit/ per unit					
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
(A) Raw materials:						
Natural gas for:						
Feedstocks..... Mcf	0.50	23.0	11.50	21.0	10.50	21.0
Heat and power..... Do	.50	15.0	7.50	17.0	8.50	17.0
Total..... Do	.50	38.0	19.00	38.0	19.00	38.0
(B) Variable costs:						
Cooling water..... Mgal	.02	41.0	.82	67.0	1.34	67.0
Boiler feed water..... Do	.50	.6	.30	.5	.25	.5
Catalysts and chemicals... Dollars			.43		.58	
Electricity..... kWh	.01	624.0	6.24	35.0	.35	35.0
Labor..... Man-hr	4.00	.3	1.20	.2	.80	.1
Total.....			8.99		3.32	
(C) Fixed costs:						
Maintenance.....			7.17		5.10	
Taxes and insurance.....			2.87		2.55	
Depreciation.....			9.56		8.50	
Interest.....			5.74		5.10	
Overhead.....			1.20		.80	
Total.....			26.54		22.05	
(D) Subtotal (A+B+C).....			54.53		44.37	
(E) Interest on working capital.....			.62		.52	
(F) Return on investment.....			31.75		28.05	
(G) Total gate price (D+E+F).....			86.90		72.94	

1/ Mcf means 1,000 cubic feet. Mgal means 1,000 gallons. kWh means kilowatt-hours.

Table 12--Operating costs of a 1,000-ton per day ammonia plant at different natural gas costs

Item	Input measures		Cost per unit	Cost per ton	Cost per unit	Cost per ton
	Unit 1/	Units per ton				
<u>Dollars</u>						
(A) Raw materials						
Natural gas for:						
Feedstocks.....	Mcf	21.00	1.00	21.00	1.50	31.50
Heat and power.....	Do	17.00	1.00	17.00	1.50	25.50
Total.....	Do	38.00	1.00	38.00	1.50	57.00
(B) Variable costs:						
Cooling water.....	Mgal	67.00	.02	1.34	.02	1.34
Boiler feed water.....	Do	.50	.50	.25	.50	.25
Catalysts and chemicals:	Do			.58		.58
Electricity.....	kWh	35.00	.01	.35	.01	.35
Labor.....	Man-hr	.12	4.00	.48	4.00	.48
Total.....				3.00		3.00
(C) Fixed costs:						
Maintenance.....				4.29		4.29
Taxes and insurance.....				2.15		2.15
Depreciation.....				7.14		7.14
Interest.....				4.29		4.29
Overhead.....				.36		.36
Total.....				18.23		18.23
(D) Subtotal (A+B+C).....				59.23		78.23
(E) Interest on working capital.....				.71		.96
(F) Return on investment.....				<u>24.97</u>		<u>26.23</u>
(G) Total gate price (D+E+F).....				84.91		105.42

1/ Mgal means 1,000 gallons. kWh means kilowatt-hours. Mcf means 1,000 cubic feet.

Table 13--Investment and operating costs for three sizes of total recycle urea plants

Item	INVESTMENT AND WORKING CAPITAL					
	300-ton-per day plant		600-ton-per day plant		1,000-ton-per day plant	
	Cost per ton		Cost per ton		Cost per ton	
	Million dollars	Dollars	Million dollars	Dollars	Million dollars	Dollars
Investment						
Battery limits.....	7.0	23,333	11.3	18,383	16.3	16,300
Off site facilities.....	1.4	4,667	2.2	3,667	3.8	3,800
Total plant investment.....	8.4	28,000	13.5	22,050	20.1	20,100
Working capital.....	1.1	3,667	2.2	3,667	3.7	3,700
Total investment and capital.....	9.5	31,667	15.7	25,717	23.8	23,800
	OPERATING COSTS					
	Input measures					
	Unit ^{1/} Cost	Units per ton	Cost per ton	Units per ton	Cost per ton	Units per ton
	per unit					
	Dollars		Dollars		Dollars	
(A) Raw materials						
Anhydrous ammonia.....	Tons 50.00	0.58	29.00	0.58	29.00	0.58
Carbon dioxide.....	Do 0	.77	0	.77	0	.77
Total.....			29.00		29.00	
(B) Variable costs:						
Cooling water.....	Mgal .02	20.00	.40	20.00	.40	20.00
Steam.....	Mlb .50	2.20	1.10	2.20	1.10	2.20
Electricity.....	kWh .01	171.00	1.71	171.00	1.71	171.00
Labor.....	Man-hr 4.00	.15	.60	.15	.60	.15
Total.....			3.81		3.81	
(C) Fixed costs:						
Maintenance.....			4.12		3.31	
Taxes and insurance.....			1.65		1.33	
Depreciation.....			5.48		4.42	
Interest.....			3.30		2.65	
Overhead.....			.60		.60	
Total.....			15.15		12.31	
(D) Subtotal (A+B+C).....			47.96		45.12	
(E) Interest on working capital.....			.45		.44	
(F) Return on investment.....			18.72		15.44	
(G) Total gate price (D+E+F).....			67.13		61.00	

1/ Mgal means 1,000 gallons. Mlb means 1,000 pounds. kWh means kilowatt-hours.

Table 14--Investment and operating costs for three sizes of high pressure nitric acid plants (100% HNO3)

Item	INVESTMENT AND WORKING CAPITAL						
	250-ton-per day plant		400-ton-per day plant		800-ton-per day plant		
	Cost per ton		Cost per ton		Cost per ton		
	Million dollars	Dollars	Million dollars	Dollars	Million dollars	Dollars	
Investment							
Battery limits.....	4.3	17,200	6.0	15,000	9.3	11,625	
Off site facilities.....	1.3	5,200	1.8	4,500	2.8	3,500	
Total plant investment.....	5.6	22,400	7.8	19,500	12.1	15,125	
Working capital.....	.5	2,000	.8	2,000	1.6	2,000	
Total investment and capital.....	6.1	24,400	8.6	21,500	13.7	17,125	
	OPERATING COSTS						
	Input measures	Units per ton	Cost per ton	Units per ton	Cost per ton	Units per ton	Costs per ton
	Unit 1/ Cost						
	per unit						
	Dollars		Dollars		Dollars		Dollars
(A) Raw materials							
Anhydrous ammonia.....	Tons 50.00	.292	14.60	.292	14.60	.292	14.60
(B) Variable costs:							
Cooling water.....	Mgal .02	36.000	.72	36.000	.72	36.000	.72
Boiler feedwater.....	Do .50	.410	.21	.410	.21	.410	.21
Steam (credit).....	Mlb .50	.300	-.15	.300	-.15	.300	-.15
Electricity.....	kWh .01	10.000	.10	10.000	.10	10.000	.10
Labor.....	Man-hr 4.00	.170	.68	.170	.68	.170	.68
Air.....	Mcf .02	1.300	.03	1.300	.03	1.300	.03
Platinum gauze.....	Troy oz 150.00	.005	.75	.005	.75	.005	.75
Total.....			2.34		2.34		2.34
(C) Fixed costs							
Maintenance.....			3.29		2.87		2.22
Taxes and insurance.....			1.32		1.15		.89
Depreciation.....			4.38		3.82		2.96
Interest.....			2.71		2.30		1.78
Overhead.....			.68		.68		.68
Total.....			12.66		10.82		8.53
(D) Subtotal (A+B+C).....			29.60		27.76		25.47
(E) Interest on working capital.....			.25		.24		.23
(F) Return on investment.....			14.38		12.67		10.05
(G) Total gate price (D+E+F).....			44.23		40.67		35.75

1/ Mgal means 1,000 gallons. Mlb means 1,000 pounds. Mcf means 1,000 cubic feet. kWh means kilowatt-hours.

Table 15--Investment and operating costs for three sizes of prilled ammonium nitrate plants

Item	INVESTMENT AND WORKING CAPITAL						
	225-ton-per day plant		400-ton-per day plant		800-ton-per day plant		
	Cost per ton		Cost per ton		Cost per ton		
	Million dollars	Dollars	Million dollars	Dollars	Million dollars	Dollars	
Investment							
Battery limits.....	4.5	20,000	6.8	17,000	11.0	13,750	
Off site facilities.....	.6	2,667	1.0	2,500	1.7	2,125	
Total plant investment.....	5.1	22,667	7.8	19,500	12.7	15,875	
Working capital.....	1.4	6,222	2.1	5,250	3.7	4,625	
Total investment and capital.....	6.5	28,889	9.9	24,750	16.4	20,500	
OPERATING COSTS							
Input measures		Units per ton	Cost per ton	Units per ton	Cost per ton	Units per ton	Cost per ton
Unit 1/ Cost							
per unit							
Dollars			Dollars		Dollars		Dollars
(A) Raw materials:							
Nitric acid.....	Tons 40.00	0.763	30.52	0.763	30.52	0.763	30.52
Anhydrous ammonia.....	Do 50.00	.208	10.40	.208	10.40	.208	10.40
Total.....			40.92		40.92		40.92
(B) Variable costs:							
Cooling water.....	Mgal .02	35.00	.70	35.00	.70	35.00	.70
Steam.....	Mlb .50	.50	.25	.50	.25	.50	.25
Electricity.....	kWh .01	30.00	.30	30.00	.30	30.00	.30
Labor.....	Man-hr 4.00	.43	1.72	.24	.96	.12	.48
Total.....			2.97		2.21		1.73
(C) Fixed costs:							
Maintenance.....			3.39		2.88		2.33
Taxes and insurance.....			1.36		1.15		.93
Depreciation.....			4.51		3.84		3.10
Interest.....			2.71		2.30		1.86
Overhead.....			1.72		.96		.48
Total.....			13.69		11.13		8.70
(D) Subtotal A+B+C).....			57.58		54.26		51.35
(E) Interest on working capital.....			.72		.62		.56
(F) Return on investment.....			17.09		14.60		12.07
(G) Total gate price (D+E+F).....			75.39		69.48		63.98

1/ Mgal means 1,000 gallons. Mlb means 1,000 pounds. kWh means kilowatt-hours.

Table 16--Investment and operating costs for three sizes of granular diammonium phosphate plants (18-46-0)

Item	INVESTMENT AND WORKING CAPITAL					
	500-ton-per day plant		975-ton-per day plant		1,450-ton-per day plant	
	Cost per ton		Cost per ton		Cost per ton	
	Million dollars	Dollars	Million dollars	Dollars	Million dollars	Dollars
Investment						
Battery limits.....	1.4	2,800	2.3	2,359	2.7	1,862
Off site facilities.....	.3	600	.5	513	.6	414
Total plant investment.....	1.7	3,400	2.8	2,872	3.3	2,276
Working capital.....	4.5	9,000	8.8	9,000	13.1	9,000
Total investment and capital.....	6.2	12,400	11.6	11,872	16.4	11,276
OPERATING COSTS						
Input measures						
Unit 1/ Cost		Units per ton	Cost per ton	Units per ton	Cost per ton	Units per ton
per unit						
Dollars			Dollars		Dollars	
(A) Raw materials:						
Anhydrous ammonia.....	Tons 50.00	0.22	11.00	0.22	11.00	0.22
Phosphoric acid.....	Do 70.00	.87	60.90	.87	60.90	.87
Total.....			71.90		71.90	
(B) Variable costs:						
Treated water.....	Mgal .10	.07	.01	.07	.01	.07
Electricity.....	kWh .01	20.00	.20	20.00	.20	20.00
Fuel oil.....	Gal .20	6.88	1.38	6.88	1.38	6.88
Labor.....	Man-hr 4.00	.18	.72	.18	.72	.18
Total.....			2.31		2.31	
(C) Fixed costs:						
Maintenance.....			.50		.42	
Taxes and insurance.....			.20		.17	
Depreciation.....			.66		.56	
Interest.....			.40		.34	
Overhead.....			.72		.72	
Total.....			2.48		2.21	
(D) Subtotal (A+B+C).....			76.69		76.42	
(E) Interest on working capital.....			1.07		1.07	
(F) Return on investment.....			7.31		6.98	
(G) Total gate price (D+E+F).....			85.07		84.47	

1/ Mgal means 1,000 gallons. kWh means kilowatt-hours.

Table 17--Use of phosphate rock in phosphatic products

Use	Year ending June 30, 1970			Year ending June 30, 1975		
	Rock :	P2O5	Percent P2O5	Rock :	P2O5	Percent P2O5
	used :	content	content	used :	content	content
	1,000 tons		Percent	1,000 tons		Percent
Phosphoric acid (wet process)	10,071	3,161	27.2	25,392	7,845	53.0
Electric furnace phosphorus	6,614	1,729	14.8	5,898	1,555	10.5
Ordinary superphosphate	4,586	1,500	12.9	1,142	354	2.4
Triple superphosphate	3,899	1,265	10.9	1,470	423	3.3
Direct application to the soil	127	38	.3	750	237	1.6
Nitric phosphate	-	-		-	-	-
Stock and poultry feed	-	-		257	87	.5
Fertilizer filler	1,237	404	3.5	-	-	-
Other fertilizers						
Other uses				1		
Total domestic use	26,534	8,097	69.5	34,910	10,560	71.4
Exports	10,921	3,546	30.5	13,191	4,238	28.6
Total use	37,455	11,643	100.0	48,101	14,798	100.0

Source: (57)

Table 18--U.S. supply and use of wet process
phosphoric acid, 1975/76

Item	:	1,000 tons P2O5
Supply:	:	
Production	:	7,805
+Imports	:	75
-Exports	:	1,678
-Reduction in inventories	:	33
Available domestic supply	:	6,204
Use:	:	
Fertilizer	:	
Ammonium phosphates	:	
Fluid (including mixtures)	:	607
Total ammonium phosphates	:	2,765
Other solid mixed fertilizers	:	1,085
Concentrated superphosphate	:	1,619
Direct application	:	52
Total fertilizer use	:	5,521
Other domestic uses	:	633
Total utilization	:	6,204

Sources: (35, 56).

Table 19--Estimated U.S. supply of phosphates for fertilizers, 1974/75

Item	P2O ₅ supply
(A) Supply from domestic production:	
Normal and enriched superphosphates	612
Concentrated superphosphate	1,569
Ammonium phosphates <u>1/</u>	2,572
All other <u>2/</u>	1,916
Total	<u>6,669</u>
(B) Imports:	
Concentrated superphosphate	26
Ammonium phosphates	106
All other	142
Total	<u>274</u>
(C) Exports:	
Normal superphosphate	4
Concentrated superphosphate	502
Ammonium phosphates	1,003
All other	373
Total	<u>1,882</u>
(D) Net domestic supply (A+B-C)	5,061

1/ Liquid and solid ammonium phosphates, excluding those combined with potash salts in the process of manufacture.

2/ Includes inactive phosphates, sodium phosphate, wet base goods, natural organics, phosphate rock, colloidal phosphate, basic slag, wet- and furnace-process, phosphoric acid for liquid and solid mixed fertilizers and direct application, and ammonium phosphates combined with potash salts in the process of manufacture.

Source: (35).

Table 20--Capacity, capacity utilization, value, and price of phosphate rock in the United States since 1967

Year	Capacity	Capacity utilization <u>1/</u>	Value <u>2/</u>	Price <u>3/</u>
	<u>Million tons</u>	<u>Percent</u>	<u>Dollars per ton</u>	
1967	41.3	96	6.64	10
1968	43.0	96	6.12	10
1969	43.0	88	5.57	10
1970	47.9	81	5.26	10
1971	47.9	81	5.26	10
1972	47.9	85	5.10	10
1973	49.7	85	5.66	16-23
1974	53.1	86	10.92	<u>4/</u> 52
1975	57.0	86	22.67	52
1976	61.1	NA	NA	NA

NA = not available.

1/ Production divided by capacity.

2/ F.o.b. mine.

3/ List price, f.o.b. New York, 75-77 percent bone phosphate of lime (BPL) rock. BPL may be converted to P2O5 by 1 percent BPL = .458 percent P2O5.

4/ June

Sources: (35, 38).

Table 21--Capacity, capacity utilization, and price of phosphoric acid in the United States since 1960

Year	Capacity P205	Capacity utilization	Price <u>1/</u>
	<u>Million tons</u>	<u>Percent</u>	<u>Dollars</u>
1960	1.3	NA	NA
1965	3.0	100	NA
1966	4.3	96	1.62
1967	5.9	77	1.72
1968	5.5	76	1.83
1969	5.3	77	1.06
1970	5.6	85	1.05
1971	5.4	90	1.17
1972	5.7	100	1.20
1973	6.3	97	1.22
1974	6.6	95	3.05
1975	6.9	NA	3.47
1976	9.0	NA	3.20

NA = not available.

1/ Per unit of P205 from merchant acid, 52-54 percent P205, f.o.b. New York.

Sources: (35, 38, 56)

Table 22--Capacity, capacity utilization, and price of concentrated superphosphate in the United States since 1960

Year	Capacity (P2O5)	Capacity utilization	Price <u>1/</u>
	<u>Million tons</u>	<u>Percent</u>	<u>Dollars</u>
1960	NA	NA	81
1961	NA	NA	
1962	NA	NA	84
1963	NA	NA	
1964	1.44	85	80
1965	1.70	86	81
1966	2.07	73	83
1967	2.32	64	84
1968	2.20	63	78
1969	2.00	68	74
1970	2.00	73	75
1971	1.76	86	76
1972	1.80	92	78
1973	2.20	73	87
1974	2.10	82	150
1975	2.2	71	214
1976	2.7		

NA = not available.

1/ Average price per ton of product paid by farmers.

Sources: (35, 38, 56, 60).

Table 23--Estimated global phosphate resources, 1976

Location	Reserves ^{1/}	Other resources	Total resources	Percentage of total
	Million tons			Percent
North America				
United States	3,220	1,660	4,880	
Other	2	2	4	
Total	3,222	1,662	4,884	5.95
South America	80	420	500	.61
Union of Soviet Socialist Republics	800	3,200	4,000	4.88
Europe	30	70	100	.12
Africa				
Morocco	18,000	40,000	58,000	
South Africa	3,000	1,000	4,000	
Other	1,080	2,920	4,000	
Total	22,080	43,920	66,000	80.47
Asia				
Vietnam	100	50	150	
Syria	200	300	500	
Jordan	40	2,500	2,540	
Other	120	80	200	
Total	460	2,930	3,390	4.13
Australia	1,000	2,000	3,000	3.66
Pacific Islands	120	30	150	.18
World total	27,792	54,232	82,024	100.00

^{1/} Estimated recoverable reserves at 1975 prices.

Source: (47).

Table 24--U.S. phosphate reserves and resources, 1976

Region	Reserves <u>1/</u>		Other Resources	Total reserves and resources	
	Quantity	Percentage of total		Quantity	Percentage of total
	Million tons P2O5	Percent		Million tons P2O5	Percent
Central Florida	1,000	31.1	700	1,700	34.8
North Florida	200	6.2	60	260	5.3
North Carolina	1,000	31.1	200	1,200	24.6
Tennessee	20	0.5	0	20	.4
Idaho	800	24.8	500	1,300	26.6
Utah	100	3.1	100	200	4.1
Wyoming	50	1.6	50	100	2.1
Montana	50	1.6	50	100	2.1
Total	3,220	100.0	1,660	4,880	100.0

1/ Estimated recoverable reserves at 1975 prices.

Source: (47).

Table 25--Global consumption and production of phosphate rock, 1974

Area	Consumption		Production	
	Quantity	Percentage	Quantity	Percentage
	Million tons	Percent of total	Million tons	Percent of total
West Europe	22.3	18.4	0	0
Belgium	2.7	2.2	0	0
France	6.3	5.1	0	0
Italy	2.2	1.8	0	0
Netherlands	2.5	2.0	0	0
Federal Republic of Germany	3.8	3.0	0	0
Spain	3.1	2.5	0	0
United Kingdom	2.2	1.8	0	0
East Europe	21.5	17.3	24.8	20.4
Poland	3.3	2.6	0	0
USSR	18.2	14.7	24.8	20.4
North America	38.6	31.1	45.7	37.6
Canada	3.9	3.1	0	0
United States	34.7	28.0	45.7	37.6
Asia	9.1	7.3	7.0	5.8
People's Republic of China	4.6	3.7	3.3	2.7
Japan	4.3	3.4	0	0
Christmas Island	.2	.2	1.9	1.6
Jordan	0	0	1.8	1.5
Oceania	3.4	2.7	0	0
Australia	3.4	2.7	0	0
Africa	2.2	1.8	31.0	25.4
Morocco	.7	.6	21.3	17.5
Spanish Sahara	0	0	2.6	2.1
Togo	0	0	2.8	2.3
Tunisia	1.5	1.2	4.3	3.5
World total	124.0	100.0	121.6	100.0

Source: (53).

Table 26 --Marketable production of phosphate rock in the United States
in selected years since 1880

Year	Marketable phosphate rock produced in--				
	United States	South Carolina	Florida and North Carolina	Tennessee	Western States
			<u>1,000 tons</u>		
1880	236	236			
1900	1,659	360	791	508	
1920	4,518	49	3,773	696	
1940	4,558		3,117	1,256	185
1950	12,448		9,629	1,649	1,170
1960	18,885		13,602	2,001	3,285
1964	25,709		19,161	2,734	3,814
1966	39,094		29,827	3,175	6,092
1968	41,251		33,032	3,149	5,070
1970	38,738		31,278	3,163	4,297
1971	38,886		32,151	2,571	4,164
1972	37,826		31,121	2,150	4,555
1973	42,100		34,400	2,500	5,200
1974	45,700		37,000	2,400	6,300
1975	48,893		40,761	2,247	5,885

Source: (57).

Table 27--Interrelatedness of components of phosphate sector, 1976

Product	Phosphate rock			Sulfuric acid			Phosphoric acid 1/			Ammonium phosphates			Concentrated superphosphate			Normal superphosphate		
	No. of firms	% of U.S. capacity	% of U.S. capacity	No. of firms	% of U.S. capacity	% of U.S. capacity	No. of firms	% of U.S. capacity	% of U.S. capacity	No. of firms	% of U.S. capacity	% of U.S. capacity	No. of firms	% of U.S. capacity	% of U.S. capacity	No. of firms	% of U.S. capacity	% of U.S. capacity
	1,000 tons	Percent	Percent	1,000 tons	Percent	Percent	1,000 tons	Percent	Percent	1,000 tons	Percent	Percent	1,000 tons	Percent	Percent	1,000 tons	Percent	Percent
Phosphate rock	22	61,100	100	14	54,650	89	11	45,200	74	13	54,300	89	10	42,200	69	9	39,200	64
Sulfuric acid	14	19,661	42	70	47,300	100	23	34,759	73	24	31,300	66	15	24,935	53	18	19,949	42
Phosphoric acid 1/	11	4,459	49	23	7,769	85	26	9,089	100	24	8,324	92	15	6,703	74	13	4,854	53
Ammonium phosphates	13	2,700	61	24	4,570	93	24	4,590	94	30	4,907	100	15	3,362	69	13	2,662	54
Concentrated superphosphate	10	1,660	62	15	2,689	100	15	2,689	100	15	2,689	100	15	2,689	100	11	1,737	65
Normal superphosphate	9	517	63	18	627	76	13	465	57	13	462	56	11	484	59	28 2/	822	100

1/ Wet process.

2/ Firm reporting productive capacity. There are approximately 45 firms with capacity to produce normal superphosphate.

Sources: (18, 51).

Table 28--Regional capacity to produce concentrated superphosphate,
1976

Region	Production capacity
	<u>1,000 tons P2O5</u>
Northeast	0
Appalachian	164
Southeast	2,102
Lake States	0
Corn Belt	45
Delta States	126
Northern Plains	0
Southern Plains	0
Mountain	252
Pacific	0
United States	2,689

Source: (51).

Table 29--Regional capacity to produce ammonium phosphates, 1976

Region	Production capacity
	<u>1,000 tons P2O5</u>
Northeast	0
Appalachian	104
Southeast	1,934
Lake States	10
Corn Belt	504
Delta States	1,474
Northern Plains	61
Southern Plains	281
Mountain	342
Pacific	200
United States	4,907

Source: (51).

Table 30--Prices of a 20-pound unit of K20 since 1922

Year	Price ^{1/}
	<u>Dollars</u>
1922	0.67
1923	.63
1925	.62
1930	.68
1935	.42
1940	.52
1941	.52
1945	.52
1950	.37
1952	.40
1969	.34
1970	.34
1971	.35
1972	.34
1973	.41
1974	.60
1975	.68
1976	.68

^{1/} Prices 1922- 52 are for bulk shipments, including cost, insurance, and freight, Atlantic and Gulf ports; for 1969- 76, prices are for large lots, f.o.b. New York.

Sources: (17, 36).

Table 31--U.S. and Canadian production capacity, output, and prices of potassium chloride since 1964.

Year	Production capacity		Output	Prices paid by U.S. farmers
	United States	Canada	United States	
	<u>Million tons K2O</u>			<u>Dollars per ton</u>
1964	3.0	1.1	2.9	54
1965	3.5	1.4	3.1	53
1966	3.6	1.6	3.3	55
1967	4.0	2.0	3.3	53
1968	3.0	3.0	2.7	45
1969	3.4	6.4	2.8	48
1970	3.5	7.7	2.7	54
1971	3.0	7.6	2.6	58
1972	3.1	7.6	2.1	58
1973	3.0	7.6	2.7	62
1974	3.0	8.3	2.6	81
1975	2.9	8.3	2.3	102
1976	3.0	7.6	2.1	96

Sources: (31, 49, 60).

Table 32--Estimated global potash resources, 1974

Location	Reserves ^{1/}	Other resources ^{2/}	Total resources	Percent of total
	- - - Million tons - - -			Percent
North America				
Canada	5,000	69,000	74,000	84.9
United States	200	200	400	.5
Total	5,200	69,200	74,400	85.4
South America	10	27	37	<u>3/</u>
Europe				
France	100	100	200	.2
Federal Republic of Germany	2,700	2,700	5,400	6.2
German Democratic Republic	1,800	1,800	3,600	4.1
Union of Soviet Socialist Republics	800	1,000	1,800	2.1
Others	115	190	305	.4
Europe total	5,515	5,790	11,305	13.0
Asia				
Israel and Jordan	240	1,000	1,240	1.4
Others	5	5	10	<u>3/</u>
Total	245	1,005	1,250	1.4
Africa	20	95	115	.1
Other	10	10	20	<u>3/</u>
World total	11,000	76,127	87,127	100.

^{1/} Estimated recoverable reserves at average 1974 prices.

^{2/} Include undiscovered mineral deposits, whether recoverable or of sub-economic grade, that are geologically predictable as existing in known districts.

^{3/} Less than 0.1 percent.

Source: (31).

Table 33--Movement of fertilizer materials by mode of transportation 1/

Mode of transportation and year	Anhydrous ammonia	Ammoniating and nitrogen fertilizer solutions	Fertilizer <u>2/</u>
		<u>Percent</u>	
Rail:			
1967.....	71	59	65
1972.....	40	47	58
Motor carrier:			
1967.....	5	11	9
1972.....	24	31	23
Private truck:			
1967.....	.4	2	9
1972.....	5	6	13
Water:			
1967.....	23	27	16
1972.....	32	17	6
Other, unknown:			
1967.....	0	.4	.2
1972.....	0	.2	.1

1/ Totals may not add to 100 because of rounding.

2/ Includes ammoniating and nitrogen fertilizer solutions and other materials but excludes anhydrous ammonia.

Source: (55).

REFERENCES

- (1) Axelrod, L.C., and T.E. O'Hare. "Aspects of Large-Scale Ammonia Production." Fertilizer Production, Technology, and Use. United Nations, New York, 1965, pp. 165-168.
- (2) Ayers, Jeannie H. "Ammonium Nitrate." Chemical Economics Handbook. Stanford, Calif., Stanford Research Institute, Jan. 1976, pp. 756.4000A-756.4008.
- (3) _____. "Urea." Chemical Economics Handbook. Stanford, Calif., Stanford Research Institute, March and Aug. 1976, pp. 756.2000A-756.2008G.
- (4) Blakeney, Allan. "Saskatchewan's Potash Outlook." Speech presented at World Fertilizer Conference, New York, Sept. 21, 1976. The Fertilizer Institute, Washington, D.C.
- (5) Blue, Thomas A. "Ammonium Phosphates." Chemical Economics Handbook. Stanford, Calif., Stanford Research Institute, Nov. 1973, pp. 760.5000A-760.5006D.
- (6) _____. "Ammonium Sulfate." Chemical Economics Handbook. Stanford, Calif., Stanford Research Institute, Aug. 1967, pp. 708.5020A-708.5020B.
- (7) _____. "Ammonium Sulfate." Tabulations from North American Fertilizer Plants Survey, Stanford Research Institute, 1976.
- (8) _____. "Anhydrous Ammonia." Tabulations from North American Fertilizer Plants Survey, Stanford Research Institute, 1976.
- (9) _____. "Nitric Acid." Chemical Economics Handbook. Stanford, Calif., Stanford Research Institute, 1968, pp. 750.5020A-750.6060.
- (10) _____. "Nitric Acid." Tabulations from North American Fertilizer Plants Survey, Stanford Research Institute, 1976.
- (11) _____. "Nitrogen Solutions." Tabulations from North American Fertilizer Plants Survey, Stanford Research Institute, 1976.
- (12) Borgars, D.J. "The Naptha Reforming Process Used by Imperial Chemical Industries Limited for the Production of Ammonia." Fertilizer Production, Technology, and Use. United Nations Industrial Development Organization, New York, 1965.
- (13) Buividas, L.J., J.A. Finneran, and O.J. Quartulli. Alternative Ammonia Feedstocks. M.W. Kellogg Engineering Information Series, reprinted from Chemical Engineering Progress, Oct. 1974.
- (14) Cathcart, J.B., and R.A. Gulbransen. Phosphate Deposits. U.S. Geological Survey Paper 820, 1973, pp. 515-525.
- (15) Caves, Richard. American Industry: Structure, Conduct, and Performance. Second Edition. Englewood Cliffs, N.J., Prentice-Hall, 1967.
- (16) Charlton, W.T., J.D. Crerar, and R.C. Akroyd. The Shipment of Phosphatic Materials--Some Technical and Economic Aspects. Proceedings No. 138, The Fertilizer Society, London, 1973.

- (17) Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. New York, Schnell Publishing Corp., various issues, 1973-76.
- (18) Cogswell, S.A. "Sulfuric Acid;" Chemical Economics Handbook. Stanford, Calif., Stanford Research Institute, Feb. 1976, pp. 780.1003A-780.1003S.
- (19) Dun and Bradstreet. D and B Reference Book. New York, 1976.
- (20) Erickson, Frank A. "Location of a System of Storage-Distribution Terminals for Agricultural Ammonia in the Corn Belt." Unpub. Ph.D. dissertation, Univ. Ill. at Urbana-Champaign, 1973.
- (21) Fauser, G. Nitric Acid Production from Ammonia by a Modified Pressure System. Chem. and Metallurg. Eng. 37, 1930, pp. 600-608.
- (22) Federal Energy Administration. National Energy Outlook. Washington, D.C., Feb. 1976.
- (23) Federal Trade Commission. Reports of the Federal Trade Commission on the Fertilizer Industry. Washington, D.C., 1916, 1950.
- (24) Fortune. The Hyperinflation in Plant Construction. Nov. 1975, pp. 102-107, 202, 204, 206.
- (25) Gale, John F. The Fertilizer Situation. U.S. Dept. Agr., Econ. Res. Serv., 1970-74.
- (26) _____. Market Structure of the Chemical Nitrogen Industry. Unpub. manuscript, 1970.
- (27) _____. Pipeline Progress. Unpub. manuscript, 1970.
- (28) Gillentine, Frank, and James T. Huey, Jr. "Handling of Ammonia." Agricultural Anhydrous Ammonia Technology and Use (M.H. McVickar and others, editors). Agricultural Ammonia Institute, Memphis, 1966, pp. 143-168.
- (29) Hicks, G.C., and others. Technical and Economic Evaluation of Fertilizer Intermediates for Use in Developing Countries. Bull. Y-3, Tennessee Valley Authority, 1970.
- (30) James, G. Russell. Large Ammonia Synthesis Plants: Their Effect on Production Costs and the Logistics and Economics of Domestic and World Use. Tennessee Valley Authority, Proceedings of the Fertilizer Production and Marketing Conference, Knoxville, Tenn., Oct. 4-6, 1967, pp. 27-33.
- (31) Keyes, William F. Potash, Mineral Facts and Problems 1975. U.S. Bureau of Mines, 1976.
- (32) Kimura, S. "Development of the Urea Industry." Fertilizer Production, Technology and Use. United Nations Industrial Development Organization, New York, 1965.
- (33) Kolterman, D.W., and W.W. Rennie. "Conversion of Ammonia to Urea and Ureaforms." The Chemistry and Technology of Fertilizers (V. Sauchelli, editor). Baltimore, Waverly Press, 1960, pp. 37-54.

- (34) Little, Arthur D., Inc. Economic Impact of Shortages on the Fertilizer Industry. C-77382, Report to the Federal Energy Admin., Boston, Jan. 1975.
- (35) Mahan, John N., and Homer L. Stroike. The Fertilizer Supply. U.S. Dept. Agr., Agr. Stabil. Conserv. Serv., 1966, 1971, 1975, 1976.
- (36) Markham, Jesse W. The Fertilizer Industry. Vanderbilt Press, Nashville, 1958.
- (37) Mather, J. Warren. Cooperative Fertilizer Marketing and Manufacturing. U.S. Dept. Agr., Farm. Coop. Ser., Res. Rpt. No. 24, 1972.
- (38) Matthiesen, G.C. "Introductory Remarks, The Impact of New Technology." Tennessee Valley Authority. Proceedings of the Fertilizer Production and Marketing Conference, Knoxville, Tenn., Oct. 4-6, 1967, pp. 25-27.
- (39) Meister Publishers. Farm Chemicals Handbook. Willoughby, Ohio, 1976.
- (40) Quartulli, O.J. Developments in Ammonia Production Technology. Houston, M.W. Kellogg, 1974.
- (41) Scherer, F.M. Industrial Market Structure and Economic Performance. Chicago, Rand McNally and Company, 1970.
- (42) Sharp, J.C. "Conversion of Ammonia to Fertilizer Materials." The Chemistry and Technology of Fertilizers. (V. Sauchelli, editor). Baltimore, Waverly Press, 1960, pp. 10-36.
- (43) Slack, A.V. Chemistry and Technology of Fertilizers. New York, Wiley and Sons, 1966, 1967.
- (44) Slack, A.V., and J.O. Hardesty. "Fertilizers Manufactured from Ammonia." Agricultural Anhydrous Ammonia Technology and Use. (M.H. McVickar and others, editors). Agricultural Ammonia Institute, Memphis, 1966, pp. 1-20.
- (45) Standard and Poors Corporation. Directory. New York, 1976.
- (46) _____. Middle Market Directory. New York, 1976.
- (47) Stowasser, W.F. Phosphate Rock--Mineral Facts and Problems. U.S. Bureau of Mines. Preprint Bulletin 667, 1977.
- (48) Strelzoff, Samuel. "Comparative Evaluation of Nitric Acid Processes." Fertilizer Production, Technology and Use. United Nations Industrial Development Organization, New York, 1965.
- (49) Tennessee Valley Authority. Fertilizer Trends. Muscle Shoals, Ala., various issues, 1960-73.
- (50) _____. "World Fertilizer Market Review and Outlook." U.S. and World Fertilizer Outlook. Committee Print 30-1670, U.S. Senate, Committee on Agriculture and Forestry, Washington, D.C., 1974.
- (51) _____. World Fertilizer Production Capacity (a computerized listing of fertilizer plant locations and capacities available through the Tennessee Valley Authority on a time-share basis). Dec. 31, 1975.

- (52) Turner, W. Ten Years of Single Train Ammonia Plants. M.W. Kellogg Engineering Information Series, Houston, 1974.
- (53) United Nations Food and Agriculture Organization. Annual Fertilizer Review 1974. Rome, 1975.
- (54) United Nations Industrial Development Organization. Fertilizer Manual. New York, 1967.
- (55) U.S. Bureau of the Census. Census of Transportation 1972, Commodity Transportation Survey--Area Services: Area Report 8, U.S. Summary, TC72C2-8, 1975.
- (56) _____. Inorganic Fertilizer Materials and Related Products, Current Industrial Reports, Series M28B. Various issues, 1950-76.
- (57) U.S. Bureau of Mines. Mineral Industry Surveys. Various issues, 1950-1976.
- (58) U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service. The Fertilizer Supply. Various issues, 1948-76.
- (59) _____, Economic Research Service. Farm Income Statistics. Stat. Bull. No. 557, July 1976.
- (60) _____, Statistical Reporting Service. Agricultural Prices. Various issues, 1960-76.
- (61) _____. Commercial Fertilizers: Consumption in the United States. Various issues, 1950-76.
- (62) _____. Commercial Fertilizers: Final Consumption for Year Ended June 30, 1975. Sp. Cr. 7(5-76), 1976.
- (63) Waggoner, D.R., and others. "Pilot Plant Development Work and Demonstration Plant Experience in Pan Granulation of Urea." Tennessee Valley Authority, paper Z-55, Muscle Shoals, Ala., 1974.

Appendix table 1--Salient characteristics of anhydrous ammonia and its derivatives

Product	Chemical composition	Physical form	Major inputs	Approximate percentage of nitrogen Percent
Anhydrous ammonia.....	NH ₃	Gas <u>1/</u>	Natural gas, air	82.0
Urea.....	CO(NH ₂) ₂	Solid	Anhydrous ammonia carbon dioxide	46.0
Ammonium nitrate.....	NH ₄ NO ₃	Solid	Anhydrous ammonia, nitric acid	33.5
Nitrogen solutions.....	Mixture	Liquid	Anhydrous ammonia, urea, ammonium nitrate, water <u>2/</u>	29.0 <u>3/</u>
Ammonium sulfate, synthetic.....	(NH ₄) ₂ SO ₄	Solid	Anhydrous ammonia, sulfuric acid	21.0
Monoammonium phosphate.....	NH ₄ H ₂ PO ₄	Solid	Anhydrous ammonia, phosphoric acid	11.0 <u>4/</u>
Diammonium phosphate.....	(NH ₄) ₂ HPO ₄	Solid	Anhydrous ammonia, phosphoric acid	21.0 <u>5/</u>

1/ Boils at -33° C.

2/ Nitrogen solutions are classified by their total content and sources of nitrogen. A 414(19-66-6) solution has 41.4 percent total nitrogen, 19 percent free ammonia, 66 percent ammonium nitrate, 6 percent urea, and 9 percent water.

3/ Average as reported in (61).

4/ 62 percent P205 basis.

5/ 54 percent P205 basis.

Sources: (35, 41, 56, 61).

Appendix table 2--Names of firms, locations, and capacities of operating
anhydrous ammonia plants, January 1, 1976

Company and plant location	Annual production capacity <u>1,000 tons of material</u>
Agrico Chemical (Williams Companies)	
Blytheville, Arkansas	340
Donaldsonville, Louisiana	400
Verdigris, Oklahoma	425
Agway (Felmont Oil)	
Olean, New York	82
Air Products and Chemicals	
New Orleans, Louisiana	220
Pace, Florida	75
Allied Chemical	
Geismar, Louisiana	340
Omaha, Nebraska	156
Hopewell, Virginia	350
South Point, Ohio	220
American Cyanamid	
Fortier, Louisiana	370
Amoco Oil (Standard Oil of Indiana)	
Texas City, Texas	681
Apache Powder	
Benson, Arizona	14
Atlas Chemicals (Tyler)	
Joplin, Missouri	129
Baker Industries	
Carlsbad, New Mexico	190
Conda, Idaho	95
Borden Chemical	
Geismar, Louisiana	300
California Oil Purification (USA Petrochem)	
Ventura, California	54
Camex (Cominco-American)	
Borger, Texas	400
CF Industries	
Donaldsonville, Louisiana	680
Fremont, Nebraska	41
Terre Haute	119
Chevron Chemical (Standard Oil of California)	
Pascagoula, Mississippi	475
Richmond, California	120
Fort Madison, Iowa	95
El Segundo, California	5
Collier Carbon and Chemical (Union Oil of Calif.)	
Brea, California	280
Kenai, Alaska	520
Columbia Nitrogen (Dutch State Mines, The Netherlands)	
Augusta, Georgia	140

Continued

Appendix table 2--Names of firms, locations, and capacities of operating anhydrous ammonia plants, January 1, 1976--Continued

Company and plant location	Annual production capacity 1,000 tons of material
Diamond Shamrock Dumas, Texas	160
Dow Chemical Freeport, Texas	115
E. I. DuPont de Nemours Belle, West Virginia	340
Beaumont, Texas	340
Victoria, Texas	100
Duval (Occidental) Hanford, California	42
El Paso Products (El Paso Natural Gas) Odessa, Texas	117
Farmers Chemical Tunis, North Carolina	170
Tyner, Tennessee	136
Farmland Industries Hastings, Nebraska	153
Enid, Oklahoma	412
Lawrence, Kansas	380
Fort Dodge, Iowa	215
Dodge City, Kansas	230
First Mississippi Fort Madison, Iowa	320
FMC South Charleston, West Virginia	22
Gardiner Tampa, Florida	133
Helena, Arkansas	187
Goodpasture Dimmitt, Texas	61
W. R. Grace Big Spring, Texas	100
Woodstock, Tennessee	340
Green Valley Chemical Creston, Iowa	35
Hawkeye Chemical (Skelly Oil) Clinton, Iowa	136
Hercules Hercules, California	70
Louisiana, Missouri	70

Continued

Continued

Appendix table 2--Names of firms, locations, and capacities of operating anhydrous ammonia plants, January 1, 1976--Continued

Company and plant location	Annual production capacity <u>1,000 tons of material</u>
Hooker Chemical (Occidental Petroleum)	
Lathrop, California	99
Plainview, Texas	56
Taft, Louisiana	90
Tacoma, Washington	22
Kaiser Agricultural Chemical (Kaiser Aluminum and Chemical)	
Savannah, Georgia	150
Mississippi Chemical	
Yazoo City, Mississippi	383
Pascagoula, Mississippi	165
Monsanto	
Luling, Louisiana	403
New Jersey Zinc (Gulf and Western Industries)	
Palmerton, Pennsylvania	36
Nipak (Enserch)	
Pryor, Oklahoma	101
Kerens, Texas	105
N-Ren	
Pryor, Oklahoma	83
Plainview, Texas	44
East Dubuque, Illinois	225
Carsbad, New Mexico	33
Olin	
Lake Charles, Louisiana	476
Pennwalt	
Portland, Oregon	8
Phillips Pacific Chemical	
Kennewich, Washington	150
Phillips Petroleum	
Beatrice, Nebraska	210
Pasadena, Texas	228
PPG Industries	
Natrium, West Virginia	33
Reichhold Chemicals	
St. Helens, Oregon	80
Rohm and Haas	
Deer Park, Texas	47
J. R. Simplot	
Pocatello, Idaho	94
Swift Chemical (Esmark)	
Beaumont, Texas	272
Tenneco	
Pasadena, Texas	200

Continued

Appendix table 2--Names of firms, locations, and capacities of operating anhydrous ammonia plants, January 1, 1976--Continued

Company and plant location	Annual production capacity <u>1,000 tons of material</u>
Tennessee Valley Authority Muscle Shoals, Alabama	74
Terra Chemicals Port Neal, Iowa	204
Tipperary Lovington, New Mexico	99
Triad Chemical (joint venture of Mississippi Chemical and First Mississippi) Donaldsonville, Louisiana	350
USS Agri-Chem (United States Steel) Clairton, Pennsylvania Cherokee, Alabama Geneva, Utah	325 175 70
Valley Nitrogen Producers El Centro, California Helm, California Chandler, Arizona	198 165 40
Vistron (Standard Oil of Ohio) Lima, Ohio	440
Vulcan Materials Wichita, Kansas	35
Wycon Chemical (Coastal States Gas) Cheyenne, Wyoming	139
Total	18,567

Sources: (8, 51)

Appendix table 3--Assumptions used in developing
cost budgets for nitrogen fertilizer plants

Item	Assumption
Location	Gulf Coast.
Operation	340 days per year.
Costs:	
1) Battery limits	As shown.
2) Offsite	30 percent of battery limits.
3) Working capital	1 month's raw materials plus 3 months' in-plant value of product.
4) Depreciation	15 years, straight line, no salvage value.
5) Interest	8 percent on one-half of total plant investment.
6) Taxes and insurance	2 percent of total plant investment.
7) Maintenance	4 percent of total plant investment (5 percent for reciprocating-type ammonia plants).
8) Labor	\$4 per man-hour.
9) Overhead	100 percent of labor.
10) Utilities	Natural gas, \$0.50 per thousand cubic feet; electrical power, \$.01 per kilowatt hour; cooling water, \$.02 per thousand gallons; boiler feed water makeup, \$.50 per thousand gallons; and steam, in balance in plant.
11) Return on investment	20 percent, before income taxes, of total capital.

Source: (50).

Appendix table 4--Names of firms, locations, and capacities of operating urea plants, January 1, 1976

Company and plant location	Annual production capacity <u>1,000 tons of material</u>
Agrico Chemical (Williams Companies)	
Blytheville, Arkansas	330
Donaldsonville, Louisiana	200
Verdigris, Oklahoma	210
Agway	
Olean, New York	75
Air Products and Chemicals	
Pace, Florida	23
Allied Chemical	
Geismar, Louisiana	245
Omaha, Nebraska	140
South Point, Ohio	70
American Cyanamid	
Fortier, Louisiana	145
Atlas Chemicals (Tyler)	
Joplin, Missouri	74
Borden Chemical	
Geismar, Louisiana	220
California Oil Purification (USA Petrochemicals)	
Ventura, California	132
CF Industries	
Donaldsonville, Louisiana	363
Fremont, Nebraska	18
Collier Carbon and Chemicals	
Brea, California	120
Kenai, Alaska	340
Columbia Nitrogen (Dutch State Mines, The Netherlands)	
Augusta, Georgia	38
Farmland Industries	
Dodge City, Kansas	64
Lawrence, Kansas	269
Farmers Chemical	
Tunis, North Carolina	165
Tyner, Tennessee	33
Gardiner	
Helena, Arkansas	67
Goodpasture	
Dimmitt, Texas	23
W. R. Grace	
Woodstock, Tennessee	138
Hawkeye Chemical (Skelly Oil)	
Clinton, Iowa	61

Continued

Appendix table 4--Names of firms, locations, and capacities of operating urea plants, January 1, 1976--Continued

Company and plant location	Annual production capacity 1,000 tons of material
Hercules	
Hercules, California	40
Louisiana, Missouri	95
Kaiser Agricultural Chemical (Kaiser Aluminum and Chemical)	
Savannah, Georgia	80
Mississippi Chemical	
Yazoo City, Mississippi	140
Nipak (Enserch)	
Pryor, Oklahoma	102
Kerens, Texas	70
N-Ren	
Pryor, Oklahoma	18
Plainview, Texas	45
East Dubuque, Illinois	85
Olin	
Lake Charles, Louisiana	165
Phillips Pacific Chemical	
Kennewick, Washington	38
Phillips Petroleum	
Beatrice, Nebraska	50
Premier Petrochemical (General American Oil of Texas)	
Pasadena, Texas	94
Reichhold Chemical	
St. Helens, Oregon	68
J. R. Simplot	
Pocatello, Idaho	15
Swift Chemical (Esmark)	
Beaumont, Texas	50
Tennessee Valley Authority	
Muscle Shoals, Alabama	61
Terra Chemicals	
Port Neal, Iowa	160
Triad Chemical (joint venture of Mississippi Chemical and First Mississippi)	
Donaldsonville, Louisiana	470
USS Agri-Chem (United States Steel)	
Cherokee, Alabama	25
Valley Nitrogen Producers	
El Centro, California	149
Helm, California	24
Vistron (Standard Oil of Ohio)	
Lima, Ohio	220

Continued

Appendix table 4--Names of firms, locations, and capacities of operating
urea plants, January 1, 1976--Continued

Company and plant location	:	Annual production capacity
	:	
Wycon Chemical (Coastal States Gas)	:	
Cheyenne, Wyoming	:	60
	:	
	:	
Total	:	5,887
	:	

Sources (3, 51)

Appendix Table 5--Names of firms, locations, and capacities of operating
nitric acid plants, January 1, 1976

Company and plant location	Annual production capacity <u>1,000 tons of material</u>
Agrico Chemical (Williams Companies)	
Verdigris, Oklahoma	210
Henderson, Kentucky	85
Agway	
Olean, New York	58
Air Products and Chemicals	
Pace, Florida	175
Oyster Creek, Texas	120
Allied Chemical	
Omaha, Nebraska	94
Geismar, Louisiana	230
Buffalo, New York	25
Newell, Pennsylvania	75
American Cyanamid	
Hannibal, Missouri	105
Boundbrook, New Jersey	25
Willow Island, West Virginia	25
Apache Powder	
Benson, Arizona	64
Atlas Chemicals (Tyler)	
Joplin, Missouri	122
Reynolds, Pennsylvania	23
Carolina Nitrogen (W.R. Grace)	
Wilmington, North Carolina	173
Celanese	
Bay City, Texas	83
CF Industries	
Fremont, Nebraska	26
Terre Haute, Indiana	130
Chevron Chemical (Standard Oil of California)	
Richmond, California	75
Fort Madison, Iowa	105
Kennewick, Washington	126
Collier Carbon and Chemical (Union Oil of California)	
Brea, California	50
Columbia Nitrogen (Dutch State Mines, The Netherlands)	
Augusta, Georgia	185
Cominco-American (Cominco Limited, Canada)	
Beatrice, Nebraska	136
Commercial Solvents (International Mineral and Chemical)	
Sterlington, Louisiana	145

Continued

Appendix table 5--Names of firms, locations, and capacities of operating
nitric acid plants, January 1, 1976--Continued

Company and plant location	Annual production capacity
	<u>1,000 tons of material</u>
E. I. DuPont de Nemours	
Beaumont, Texas	94
Gibbstown, New Jersey	430
Seneca, Illinois	217
DuPont, Washington	21
Orange, Texas	
Victoria, Texas	182
Louviers, Colorado	
El Paso Products (El Paso Natural Gas)	
Odessa, Texas	55
Farmers Chemical	
Tunis, North Carolina	320
Tyner, Tennessee	175
Farmland Industries	
Dodge City, Kansas	66
Lawrence, Kansas	370
Fort Dodge, Iowa	389
Gardinier	
Helena, Arkansas	85
Goodpasture	
Dimmitt, Texas	25
Gulf Oil	
Pittsburg, Kansas	300
Hawkeye Chemical (Skelly Oil)	
Clinton, Iowa	40
Hercules	
Hercules, California	65
Louisiana, Missouri	400
Bessemer, Alabama	20
Parlin, New Jersey	53
Donora, Pennsylvania	120
Hooker Chemical (Occidental Petroleum)	
Hanford, California	15
Illinois Nitrogen (a joint venture of Borden and Royster)	
Marseilles, Illinois	110
Kaiser Agricultural Chemicals (Kaiser Aluminum and Chemical)	
Savannah, Georgia	165
Tampa, Florida	42
North Bend, Ohio	80
Bainbridge, Georgia	50
Mississippi Chemical	
Yazoo City, Mississippi	381
Mobay Chemical (Bayer AG, Federal Republic of West Germany)	
Bay City, Texas	50
Natrium, West Virginia	72

Continued

Appendix table 5--Names of firms, locations, and capacities of operating
nitric acid plants, January 1, 1976--Continued

Company and plant location	Annual production capacity
	<u>1,000 tons of material</u>
Monsanto	
El Dorado, Arkansas	280
Luling, Louisiana	240
Pensacola, Florida	260
Nipak (Enserch)	
Kerens, Texas	58
Nitram Chemicals	
Tampa, Florida	120
N-Ren	
Pryor, Oklahoma	122
Pine Bend, Minnesota	179
Olin	
Lake Charles, Louisiana	168
Phillips Pacific Chemical	
Kennewick, Washington	43
Phillips Petroleum	
Beatrice, Nebraska	55
Etter, Texas	147
Reichhold Chemicals	
St. Helens, Oregon	20
Rubicon Chemicals (a joint venture of Uniroyal and ICI Limited, United Kingdom)	
Geismar, Louisiana	119
J. R. Simplot	
Pocatello, Idaho	15
Swift Chemical (Esmark)	
Beaumont, Texas	158
Tennessee Valley Authority	
Muscle Shoals, Alabama	30
Terra Chemicals	
Port Neal, Iowa	117
United States Army Ordnance	
Joliet, Illinois	421
Tyner, Tennessee	187
Radford, Virginia	228
Kingsport, Tennessee	255
Baraboo, Wisconsin	255
Lawrence, Kansas	296
Charleston, Indiana	209
Newport, Indiana	238
USS Agri-Chem (United States Steel)	
Crystal City, Missouri	100
Cherokee, Alabama	120
Geneva, Utah	90
Valley Nitrogen Producers	
El Centro, California	35

Continued

Appendix table 5--Names of firms, locations, and capacities of operating
nitric acid plants, January 1, 1976--Continued

Company and plant location	Annual production capacity <u>1,000 tons of material</u>
Vicksburg Chemical Vicksburg, Mississippi	70
Vistron (Standard Oil of Ohio) Lima, Ohio	63
Wycon Chemical (Coastal States Gas) Cheyenne, Wyoming	62
Total	11,958

Sources (10, 51)

Appendix table 6--Names of firms, locations, and capacities of operating ammonium nitrate plants, January 1, 1976

Company and plant location	Annual production capacity <u>1,000 tons of material</u>
Agrico Chemical (Williams Companies)	
Verdigris, Oklahoma	264
Henderson, Kentucky	100
Agway	
Olean, New York	71
Air Products and Chemicals	
Pace, Florida	200
Allied Chemical	
Geismar, Louisiana	300
Omaha, Nebraska	113
American Cyanamid	
Hannibal, Missouri	125
Apache Powder	
Benson, Arizona	124
Atlas Chemicals (Tyler)	
Joplin, Missouri	161
Reynolds, Pennsylvania	15
Carolina Nitrogen (W. R. Grace)	
Wilmington, North Carolina	217
CF Industries	
Fremont, Nebraska	33
Terre Haute, Indiana	144
Chevron Chemical (Standard Oil of California)	
Richmond, California	41
Fort Madison, Iowa	85
Kennewich, Washington	105
Collier Carbon and Chemical (Union Oil of California)	
Brea, California	60
Columbia Nitrogen (Dutch State Mines, The Netherlands)	
Augusta, Georgia	234
Cominco (Cominco Limited, Canada)	
Beatrice, Nebraska	173
Commercial Solvents (International Minerals and Chemical)	
Sterlington, Louisiana	120
E. I. DuPont de Nemours	
Seneca, Illinois	197
Farmers Chemical	
Tunis, North Carolina	400
Tyner, Tennessee	128

Continued

Appendix table 6--Names of firms, locations, and capacities of operating ammonium nitrate plants, January 1, 1976--Continued

Company and plant location	Annual production capacity 1,000 tons of material
Farmland Industries	
Dodge City, Kansas	80
Lawrence, Kansas	460
Gardiner	
Big River, Arkansas	100
Goodpasture	
Dimmit, Texas	31
Gulf Oil	
Pittsburgh, Kansas	360
Hawkeye Chemical (Skelly Oil)	
Clinton, Iowa	145
Hercules	
Hercules, California	80
Louisiana, Missouri	500
Bessemer, Alabama	25
Donora, Pennsylvania	150
Illinois Nitrogen	
Marseilles, Illinois	139
Kaiser Agricultural Chemical (Kaiser Aluminum and Chemical)	
Savannah, Georgia	252
Tampa, Florida	52
North Bend, Ohio	105
Bainbridge, Georgia	59
Mississippi Chemical	
Yazoo City, Mississippi	470
Mobil Oil	
Beaumont, Texas	200
Monsanto	
El Dorado, Arkansas	250
Luling, Louisiana	200
Nipak (Enserch)	
Kerens, Texas	72
Nitram	
Tampa, Florida	150
N-Ren	
Pryor, Oklahoma	99
St. Paul, Minnesota	230
Occidental Petroleum	
Hanford, California	22
Phillips Pacific Chemical	
Kennewick, Washington	55

Continued

Appendix table 6--Names of firms, locations, and capacities of operating ammonium nitrate plants, January 1, 1976--Continued

Company and plant location	Annual production capacity
	<u>1,000 tons of material</u>
Phillips Petroleum	
Beatrice, Nebraska	75
Etter, Texas	180
Reichhold Chemicals	
St. Helens, Oregon	24
J. R. Simplot	
Pocatello, Idaho	20
Terra Chemicals	
Port Neal, Iowa	143
Tennessee Valley Authority	
Muscle Shoals, Alabama	43
USS Agri-Chem (United States Steel)	
Crystal City, Missouri	100
Cherokee, Alabama	100
Geneva, Utah	100
Valley Nitrogen Producers	
El Centro, California	44
Vicksburg Chemicals	
Vicksburg, Mississippi	30
Vistron (Standard Oil of Ohio)	
Lima, Ohio	64
Wycon Chemical (Coastal States Gas)	
Cheyenne, Wyoming	73
Total	8,692

Sources: (2, 51).

Appendix table 7--Names of firms, locations, and capacities of operating ammonium phosphate plants, January 1, 1976

Company and plant location	Annual production capacity
	<u>1,000 tons of P2O5</u>
Agrico Chemical (Williams Companies)	
Pierce, Florida	46
Donaldsonville, Louisiana	709
Allied Chemical	
Geismar, Louisiana	135
Baker Industries	
Conda, Idaho	125
Marseilles, Illinois	92
Taft, Louisiana	214
Borden Chemical	
Piney Point, Florida	55
Brewster Phosphates	
Luling, Louisiana	177
Geismar, Louisiana	69
CF Industries	
Bonnie, Florida	460
Plant City, Florida	180
Conserv (Engelhard)	
Nichols, Florida	104
Collier Carbon and Chemical (Union Oil of California)	
Pittsburgh, California	25
El Paso Products (El Paso Natural Gas)	
Odessa, Texas	30
Farmland Industries	
Pierce, Florida	92
Joplin, Missouri	92
Lawrence, Kansas	61
First Mississippi	
Fort Madison, Iowa	228
Ford Motor	
Dearborn, Michigan	15
Gardiner	
Tampa, Florida	257
Helena, Arkansas	50
W. R. Grace	
Bartow, Florida	201
International Minerals and Chemical	
New Wales, Florida	233
Mississippi Chemical	
Pascagoula, Mississippi	153

Continued

Appendix table 7--Names of firms, locations, and capacities of operating ammonium phosphate plants, January 1, 1976--Continued

Company and plant location	:	Annual production capacity
		<u>1,000 tons of P2O5</u>
Mobil Chemical (Mobile Oil)	:	
Depue, Illinois	:	110
Nipak (Enserch)	:	
Kerens, Texas	:	51
Occidental Petroleum	:	
Lathrop, California	:	18
White Springs, Florida	:	303
North Idaho Phosphates (joint venture between Gulf Resources and Stauffer)	:	
Kellogg, Idaho	:	21
Olin	:	
Pasadena, Texas	:	233
Phosphate Chemicals	:	
Pasadena, Texas	:	50
Royster	:	
Mulberry, Florida	:	124
J. R. Simplot	:	
Pocatello, Idaho	:	78
Stauffer Chemical	:	
Garfield, Utah	:	56
Texasgulf	:	
Lee Creek, North Carolina	:	101
USS Agri-Chem (United States Steel)	:	
Cherokee, Alabama	:	113
Bartow, Florida	:	14
Valley Nitrogen Producers	:	
Helm, California	:	35
Chandler, Arizona	:	15
Bena, California	:	7
Total	:	5,132

Sources: (5, 51).

Appendix table 8--Phosphate rock production capacity since 1967

Firm name	1967			1971			1976		
	Rock	Percentage	Rank	Rock	Percentage	Rank	Rock	Percentage	Rank
	production	of U.S.		production	of U.S.		production	of U.S.	
	capacity	total		capacity	total		capacity	total	
	1,000 tons	Percent		1,000 tons	Percent		1,000 tons	Percent	
International Minerals and Chemicals	8,000	19	1	8,000	16	1	12,500	21	1
Agrico Chemicals/Williams	6,500	15	2	6,500	13	2	8,300	14	2
Occidental/Agricultural Chemicals	2,250	5	4	3,750	7	4	5,000	8	3
Mobil Chemical	3,050	7	3	5,900	12	3	4,700	8	4
Brewster Phosphate	2,400	6	5	3,650	7	5	4,300	7	5
Texasgulf	3,000	7	8	3,000	6	8	4,000	6	6
Swift Chemical	1,500	4	7	3,000	6	7	3,000	5	7
Stauffer Chemical	2,350	6	9	2,500	5	9	2,900	5	8
W.R. Grace	1,550	4	12	1,550	3	12	2,500	4	9
Baker Industries	650	1	16	650	1	16	2,300	4	10
Borden Chemical	1,500	4	13	1,500	3	13	1,000	1	12
Cominco	1,050	2	15	750	1	15	250	1	14
J.R. Simplot	1,600	4	14	1,000	2	14	2,000	3	11
United States Steel/Agri-Chem.	1,590	4	6	3,590	7	6	2,000	3	11
Monsanto	1,500	4	10	2,000	4	10	1,700	3	13
Gardiner	2,000	5	11	2,000	4	11	2,000	3	11
Total	40,490	97		49,340	97		58,450	96	
Top 4	20,550	49		24,150	48		30,500	50	
Top 10	34,950	84		41,890	82		49,500	81	
U.S. total	41,700	100		50,640			61,100		

Sources: (49, 51).

Appendix table 9--Phosphoric acid production capacity since 1967

Firm name	1967			1971			1976		
	Acid	Percentage	Rank	Acid	Percentage	Rank	Acid	Percentage	Rank
	production	of U.S.		production	of U.S.		production	of U.S.	
	capacity	total		capacity	total		capacity	total	
	1,000 tons	Percent		1,000 tons	Percent		1,000 tons	Percent	
CF Industries.....	200	4	14	808	14	1	1,255	14	1
Freeport Mineral.....	144	2	16	600	10	2	750	8	2
International Minerals and Chemicals..	490	9	2	0	0		750	8	3
Texasgulf.....	350	6	3	346	6	6	686	7	4
Agrico Chemical/Williams.....	0	0		0	0		670	7	5
Occidental/Agricultural Chemical.....	535	10	1	454	8	5	612	7	6
Gardinier.....	340	6	4	544	9	3	594	6	7
Beker Industries.....	0	0		0	0		567	6	8
Farmland Industries.....	253	5	10	510	0	4	510	6	9
Olin.....	300	5	6	210	4	11	427	5	10
W. R. Grace.....	320	6	5	300	5	7	330	3	11
United States Steel/Agri-Chem.....	275	5	8	266	4	8	266	3	12
J. R. Simplot.....	265	5	9	265	4	9	240	3	13
Borden Chemical.....	249	5	11	175	3	14	205	2	14
Mississippi Chemical.....	120	2	18	160	3	15	200	2	15
First Mississippi.....	0	0		0	0		190	2	16
Continental Oil.....	216	4	13	216	4	10	0		
Allied Chemical.....	229	4	12	200	3	12	160	2	17
Arco Chemical.....	0	0		190	3	13	0		
Royster.....	300	5	7	135	2	16	132	1	18
Mobil Chemical.....	130	2	17	120	2	18	125	1	19
Stauffer Chemical.....	40	1	19	100	2	19	100	1	20
New Jersey Zinc.....	150	2	15	125	2	17	0		
Engelhard.....	0	0		0	0		150	2	21
Total.....	4,860	88		5,724	97		8,922	98	
Top 4.....	1,715	31		2,462	42		3,441	38	
Top 10.....	2,896	53		4,309	74		6,821	75	
U.S. Total.....	5,459	100		5,803	100		9,089	100	

Sources: (49, 51).

Appendix table 10--Potassium production capacity in the United States and Canada since 1967

Firm Name	1967					1971					1976				
	Potash production			Percent- age of total	Rank	Potash production			Percent- age of total	Rank	Potash production			Percent- age of total	Rank
	capacity					capacity					capacity				
	United States	Canada	Total			United States	Canada	Total			United States	Canada	Total		
Potash Corporation of America.....	620	430	1,050	17	2	620	460	1,080	9	3	620	460	1,080	9	3
International Minerals and Chemicals.....	450	1,260	1,710	28	1	300	2,330	2,630	22	1	380	2,330	2,710	23	1
Kermac Potash.....	300	0	300	5	9						325	0	325	3	10
Amax.....	600	0	600	10	3	720	0	720	6	8	720	0	720	6	8
Duval.....	450	0	450	8	5	240	836	1,076	9	4	320	732	1,052	9	4
National Potash.....	350	0	350	6	8	350	0	350	3	11	315	0	315	3	11
Kerr-McGee.....						561	0	561	5	10	235	0	235	2	12
Texasgulf.....	350	0	350	6	7	350	900	1,250	10	2	186	912	1,098	9	2
Great Salt Lake.....											120	0	120	1	13
Mississippi Chemical.....											100	0	100	1	14
U.S. Borax and Chemical..	550	0	550	9	4										
U.S. Potash and Chemical..						200	0	200	2	12					
Kaiser Chemical.....	66	0	66	1	11	55	0	55	1	14	55	0	55	1	15
American Potash and Chemical.....	235	0	235	4	10										
Lithium Corporation of America.....						120	0	120	1	13					
Kalium Chemical.....	0	360	360	6	6	0	937	937	8	5	0	937	937	8	5
Alwinsol Potash.....						0	600	600	5	9	0	600	600	5	9
Noranda Mines.....						0	900	900	8	6	0	900	900	8	6
Cominco.....						0	720	720	6	8	0	720	720	6	8
Silvite of Canada.....						0	732	732	6	7	0	732	732	6	7
Others.....	10														
Total.....	3,981	2,050	6,031	100		3,516	8,415	11,931	100		3,376	8,323	11,699		
Top 4 in North America...	2,220	2,050	4,270	71		2,251	5,067	6,036	50		2,045	5,079	5,940	51	
Top 10 in North America..	3,971	2,050	6,021	100		3,516	8,415	10,647	89		3,321	8,323	10,549	90	

Sources: (49, 51)